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Magnetic Separation of Potash - Phase II

By: Central Canada Potash
Potash Corporation of Saskatchewan

For: CANMET

Contract # 01-SQ-23440-7-9226

PROJECT PART I

Bench Scale Tests to Establish Floatability of Magnetically Separated Ore and Research into Magnetic Activation of Halite

PROJECT PART II

Pilot Plant Studies: Dry Magnetic Separation of Insol from Sylvite and Halite

This study was co-funded by CANMET,
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MICROMEDIA

EXECUTIVE SUMMARY

Part One of the project involved testing a bench scale magnetic separator (with a 100 mm x 71 mm diameter roll) at the Central Canada Potash laboratory.

The magnetic separation step was incorporated in several configurations into a conventional potash milling circuit and the cleaned ore was then subject to laboratory flotation tests at various reagent rates. Test work was done on CCP mill feed which has a size range of 6 x 200 mesh. The 6 mesh is the maximum particle size for rougher flotation.

Overall KCl recovery and reagent usage was compared with parallel tests run on a conventional circuit (without magnetic separation).

Magnetic separator feed was limited to 6 x 28 mesh ore, as the separation was poor with a wider size distribution. Magnetic separation and scrubbing and desliming had to be combined to get good flotation results. In the combined circuit it was possible to cut depressant reagent by up to 50%, but overall KCl recovery was 1 - 2% lower than in a conventional circuit.

Research into magnetic activation of Halite was limited to a literature search into non-conventional magnetic separation processes. Follow-up test work was not attempted due to lack of time.

Part Two of the project involved testing a full-sized magnetic separator (with 1000 mm x 100 mm diameter roll) at the Potash Corporation of Saskatchewan pilot plant. Test variables included feed clay content, feed particle size and feed rate in a single pass arrangement. Tests were also done on reprocessing the magnetic and non-magnetic streams.

Good clay rejection was possible on closely-sized ores, but if the feed contained a wider size distribution, the throughput had to be curtailed to maintain the separation. On 3 x 6 mesh ore, a feed rate of 8 to 10 tph yielded a 90% KCl recovery and 45% WI rejection. The feed rate was halved to obtain the same separation on 6 x 28 mesh ore. The throughput was limited by the thickness of the particle layer as it passes over the Permroll, a uniform mono-layer seems to be the optimum.

RÉSUMÉ ADMINISTRATIF

Dans la première partie de l'étude, il s'agissait de procéder aux essais d'un séparateur magnétique à échelle réduite (avec un rouleau d'un diamètre de 71 mm x 100 mm) au laboratoire Central Canada Potash.

L'étape de séparation magnétique était incorporée en plusieurs configurations dans un circuit ordinaire de treatement de potasse. Le minerai nettoyé était ensuite soumis aux essais de flottation en laboratoire à différents taux de réactifs. Le test s'est produit sur une noule alimenté de CCP ayant une grosseur possible jusqu'à 6 x 200 mesh. La 6 mesh est la particule maximum pour la flotation vigoureuse.

La récupération totale de KCl et la consummation de réactif étaient ensuite comparés aux résultats d'essais effectués en parallèle sur an circuit ordinaire (c.-à-d. sans séparation magnétique).

On n'utilisait que de minerai tamix à 6 x 28 pour alimenter le séparateur magnétique puisque la séparation était pauvre en utilisant un minerair de granulométrie plus large. Pour obtenir un bon rendement de flottation, il était nécessaire de combiner la séparation magnétique, le débourbage et le deschlammage. Dans le circuit combiné, il était possible de réduire de 50% l'utilisation d'agents deprimants mais la récupération de KCl était alors réduite de 1 à 2% en comparaison de la récupération obtenue dans le circuit ordinaire.

La recherche sur l'activation magnétique de l'halite s'est trouvée limitée à une étude bibliographique portant sur les procédés de séparation magnétique utilisant de nouvelles technologies. Une contrainte de temps nous a empêché da passer à l'étape des essais.

La deuxième partie du projet avait pour but de procéder à l'essai d'un séparateur magnétique de dimensions opérationnelles (rouleau d'un diamètre de 100 mm x 1000 mm) à l'usine-pilote de la Potash Corporation de Saskatchewan. Les essais variaient les paramètres suivants: concentration d'argile, grosseur granulométrie de l'alimentation, et taux d'alimentation en configuration de passage unique. Des essais furent à nouveau traitées sur les portions magnétiques et non-magnétiques.

Un bonne élimination d'argile fut obtenue avec du minerai de granulométrie étroite, mais avec une plus large distribution granulométrique; le débit devait être réduit afin d'obtenir une bonne séparation. Un minerai de 3 x 6 mesh à un taux de 8 x 10 tonnes par heure permettait de récupérer 90% du KCl et d'éliminer 45% des matières insolubles. Le débit fut réduit de moitié afin d'obtenir la même séparation avec minerai de 6 x 28 mesh. Le débit se trouvait alors limité par l'épaisseur de la couche particulaire passant sur le Permroll et il fut conclu qu'une monocouche uniforme produisait les meilleurs résultats.

PROJECT PART I

Bench Scale Tests to Establish Floatability of Magnetically Separated Ore and Research into Magnetic Activation of Halite.

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INTRODUCTION

Research work conducted at CCP has shown that clay (water insolubles or WI) contained in potash ores can be separated in dry form by using a high intensity, high gradient, magnetic roll. (See Reference 1) This separation is possible as the clay was found to be slightly magnetic, while the sylvite (KCl) and halite (NaCl) which make up the balance of the ore are non-magnetic.

Current milling practice involves high intensity scrubbing and mechanical desliming to reject the clay, followed by conditioning and rougher flotation to concentrate sylvite values found in the ore.

The first part of this reports deals with establishing the floatability of ore which has been "deslimed" magnetically in comparison to ore which has been scrubbed and deslimed.

The second part of the report deals with magnetic activation of the halite, for the purpose of using the magnetic separation process to concentrate sylvite in the non-magnetic fraction.

A laboratory Permroll magnetic separator was obtained for these tests from Oresorters, Inc. This Permroll differs from the unit used in the original research work, in that the feed passes over the magnetic roll on a belt conveyor with the roll acting as head pulley. The Permroll is manufactured from a neodymium-iron-boron ceramic alloy and has a field strength of 1.8 tesla. Further details on the laboratory Permroll are included in Appendix I.

The test work was done on CCP mill feed which is similar to potash ores mined in the Saskatoon area.

OBJECTIVES OF TEST WORK

Establishing flotability of magnetically separated ore.

1) Establish flowsheet for incorporating magnetic separator into the desliming process.

2) Establish a parallel flowsheet with scrubbing and desliming only for comparison with Item 1).

3) Determine if advantages exist in the incorporation of a magnetic separator, in terms of the following:

   (a) minimize KCl losses in desliming.
   (b) maximizing KCl recovery in the rougher flotation step.
   (c) reduction of depressant usage for a given recovery.
   (d) reduction of collector usage for a given recovery.

Magnetic activation of halite.

1) Do a literature search to determine current state of knowledge on magnetic activation of weakly magnetic or non-magnetic materials.

2) Conduct bench scale testing to follow-up on any promising leads uncovered in the literature search.

SUMMARY

Preliminary tests established that the magnetic separator was not efficient at processing fine ore. The practical feed size for the Permroll was therefore set at 6 x 28 mesh.

Magnetic separation gave a clay rejection equal to or better than scrubbing and desliming, but resulted in a greater KCl loss. It was possible to substantially reduce these losses by reprocessing the magnetic fraction.

In flotation tests, the magnetically separated ore did not float as well as the scrubbed material due to liberation of surface clay in handling and conditioning. Excellent flotation results were achieved when magnetic separation was combined with scrubbing and desliming. Flotation recovery improved with scrubbing time, but desliming losses increased as well.

The circuit incorporating a magnetic separator had overall KCl recoveries about 1 - 2% lower than the flowsheet with the scrub-deslime alone.

Incorporation of a magnetic separator into a scrubbing and desliming circuit would reduce depressant usage in flotation by 30 - 50%, but flotation collector savings were marginal.

The literature search on halite activation included non-conventional magnetic separation processes applicable to weakly magnetic or non-magnetic materials. Most of these processes utilize chemicals which are expensive or toxic and have not been tried on a commercial scale. No bench scale work was attempted on any of the processes identified in the literature due to lack of time.

CONCLUSIONS

In the short term, magnetic separation seems to be of limited use in potash processing.

The major advantage of the process is that it allows dry separation of coarse clay from potash ore. The major disadvantage is the low feed capacity of the Permroll and the drop in separating efficiency when processing a combination of coarse and fine ore.

The literature search indicated some processes which may be used for magnetic separation of halite, but a considerable amount of bench scale testing would be required to investigate their practicality.

DISCUSSION

Flotation Test Work

1) All test work is based on three bulk samples of ore (mill feed) obtained on June 1 and 22, 1987 and January 12, 1988. They are identified as series A, B and C ores respectively. A flotation test run from a single day is identified by an alphanumeric such as series A1, series B4, etc.

Individual flotation tests are numbered as N.xx, where the N within a given series identifies the flotation feed preparation method and the .xx denotes variations in reagent dosage for a fixed value of N.

As collector performance can vary substantially with brine temperature, all flotation tests were conducted at about 80° F. The ratio of long chain collector to short chain collector was kept constant at 4:3.

2) Operation of Permroll

Technical data on the Permroll and results of preliminary test work to determine optimum settings for operation of the device are given in Appendix 1.

A suitable feed material for the Permroll was judged to be the 6 x 28 mesh ore, which amounts to about 60% of the mill feed. With the established Permroll settings, two passes gave a non-magnetic fraction with about 2% WI. This compares favourably with the 2.0 - 2.5% WI for coarse ore scrubbed and deslimed in the mill.

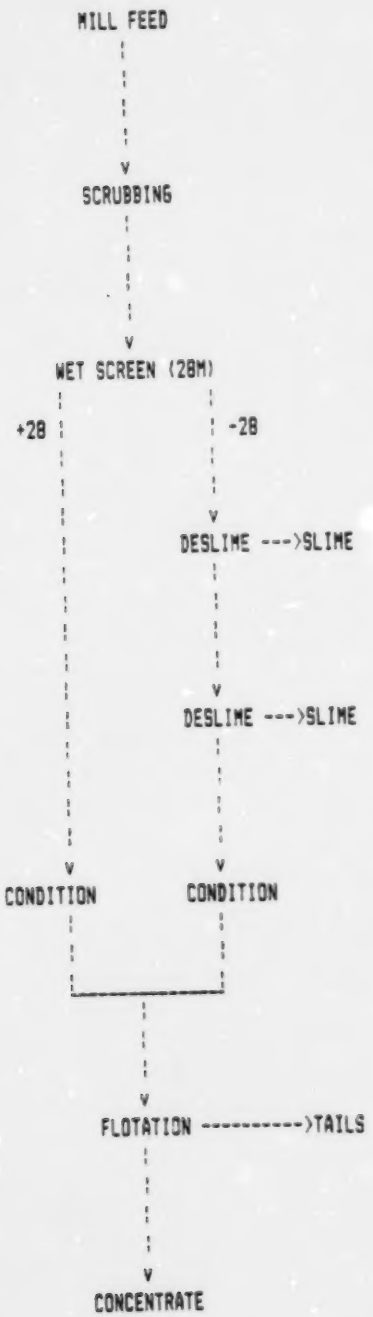
3) Series A Ore Test Work

a) Flowsheet #1 and #2 show the processing steps established for testing of series A ores. Flowsheet #1 approximates the current milling strategy and Flowsheet #2 incorporates two stages of magnetic separation for the coarse ore fraction. The laboratory procedure for Flowsheets #1 and #2 are given in Appendix 2 and Appendix 5.

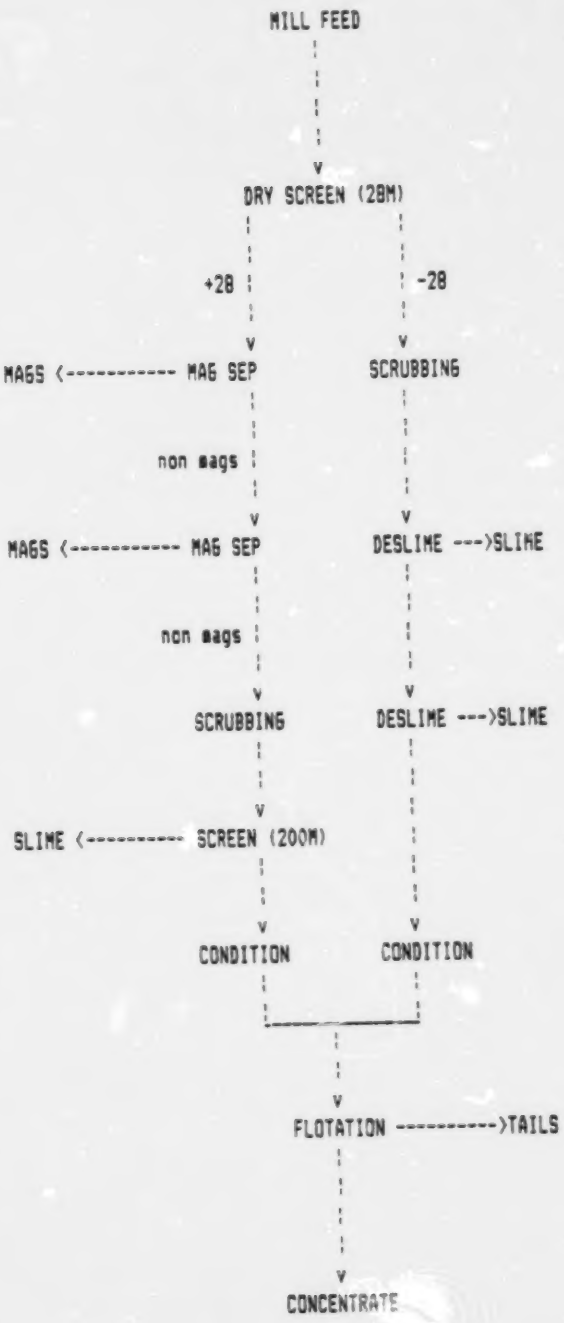
b) Table 1 in Appendix 2 gives typical fractional analysis for ores which have been processed as per Flowsheet #1 and #2 and are summarized below.

Mesh Size	Head Ore Sample Wt %	Distribution KCl	WI	Head Ore (Scrubbed) Wt %	Distribution KCl	WI	Head Ore (Mag Separation) Wt %	Distribution KCl	WI
+10	28.8	23.8	40.5	25.4	20.7	16.3	26.2	22.4	16.6
+28	64.9	62.4	66.6	59.9	57.1	30.6	58.7	56.5	26.2

FLOW SHEET WITH SCRUBBING AND DESLIMING
FLOW SHEET #1



FLOW SHEET INCORPORATING A MAGNETIC SEPERATOR
FLOW SHEET #2



The following is noted when comparing the head ore to the scrubbed material and the magnetically treated material:

i Both clay removal processes result in the weight percent distributed to the +28 mesh to be reduced by about 5%.
ii Scrubbing does not break down the potash particles significantly when compared to the magnetically separated material in the +10 and +28 mesh fraction.
iii Magnetic separation was better than scrubbing for removing clay from the +28 mesh fraction.
iv In the scrubbed sample, 11.8% of the weight was lost with the slimes for a recovery loss of 11.6% KCl, and WI rejection of 61.6%. In the magnetically separated sample (with desliming of -28 mesh) 12.0% of the weight was lost with the slime and magnetic material for a recovery loss of 8.9% KCl and WI rejection of 61.6%.

c) Results of heavy liquid tests on the magnetic separator reject are given in Appendix 2, Table 2. All fractions were floated on liquid of specific gravity 2.20.

The -10 mesh material in the float contains about 50% of the KCl rejected and is tied to about 6% of the clay. This material reports to the magnetic fraction due to its fine size and could be recovered by reprocessing on a Permroll with different settings for belt speed or splitter gate.

d) The variables tested in flotation feed preparation were as follows:

i Series A1: Flowsheet #1 with a 3 minute scrubbing time.
ii Series A2: Flowsheet #1 with a 1.5 minute scrubbing time.
iii Series A3: Flowsheet #2 without scrubbing non-mags.
iv Series A4: Flowsheet #2 with a 0.5 minutes scrubbing time for non-mags.

The variables tested in the flotation tests were as follows:

i Depressant dosage to coarse fraction.
ii Depressant dosage to fines fraction.

e) Data on flotation feed preparation losses and flotation test results are given in Appendix 2, Tables 3-7 and are summarized below. Graphical presentation of test results follow in Figures 1 - 4.

	Flotation Feed			Optimum Flotation Results	
	Assay	Distribution		Recovery	Total Depressant
Series	WI	KCl	WI	%	lb./ton
A1	1.7	87.5	29.6	86 - 89	0.28
A2	1.7	87.2	30.6	86	0.25
A3	1.8	89.0	32.6	84 - 85	0.25
A4	1.1	88.5	20.5	90 - 91	0.10

The following are evident from these results:

i Scrubbing of mill feed for 1.5 minutes or 3.0 minutes gave similar results for WI rejection and KCl losses, however, in the flotation step the feed which had been scrubbed for 1.5 minutes gave a lower recovery and the data shows more scatter.

ii Magnetic separation of the coarse fraction gave a clay rejection similar to scrubbing with a 2% lower KCl loss but flotation recovery was poor.

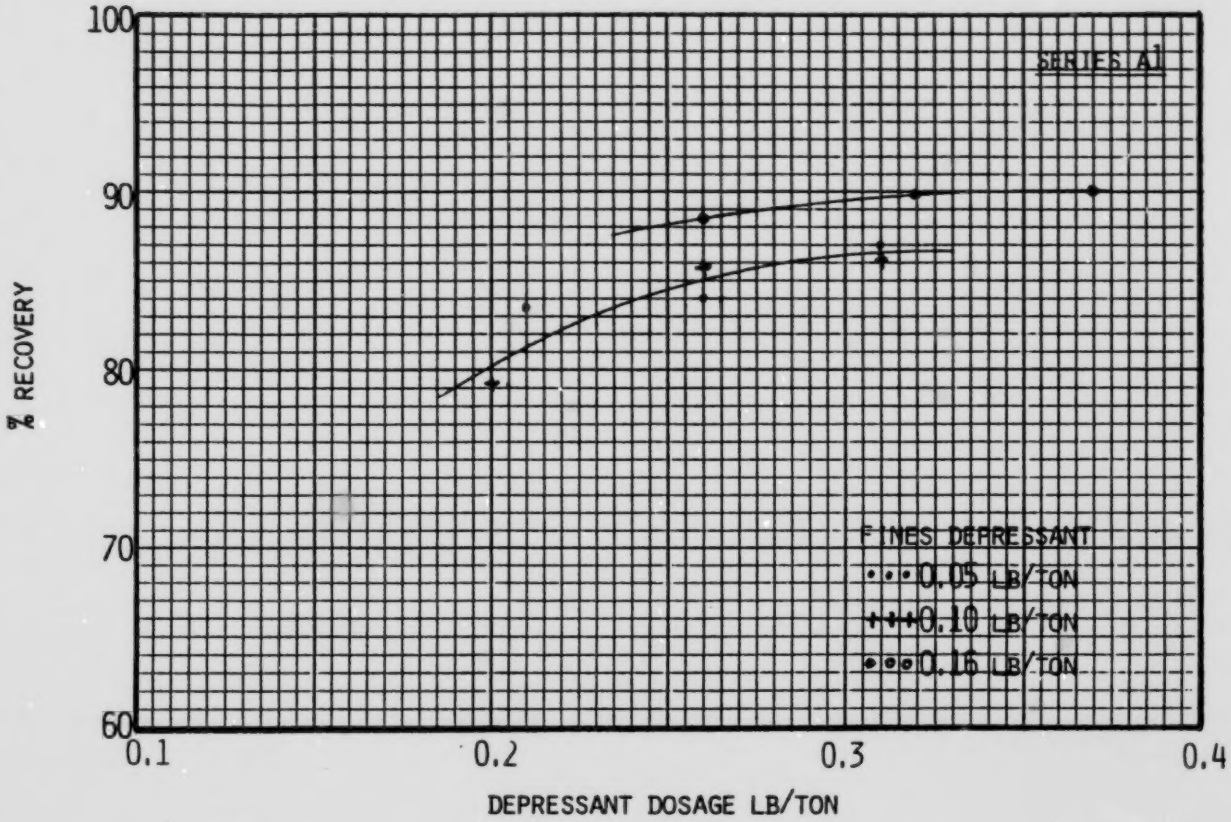
iii Magnetic separation of the coarse fraction followed by scrubbing for 0.5 minutes gave very good results for clay rejection with KCl losses only slightly higher than magnetic separation alone.

iv Series A4 flotation tests yielded a high recovery with vary low depressant dosage. This is in line with the good clay rejection reported for this series of tests.

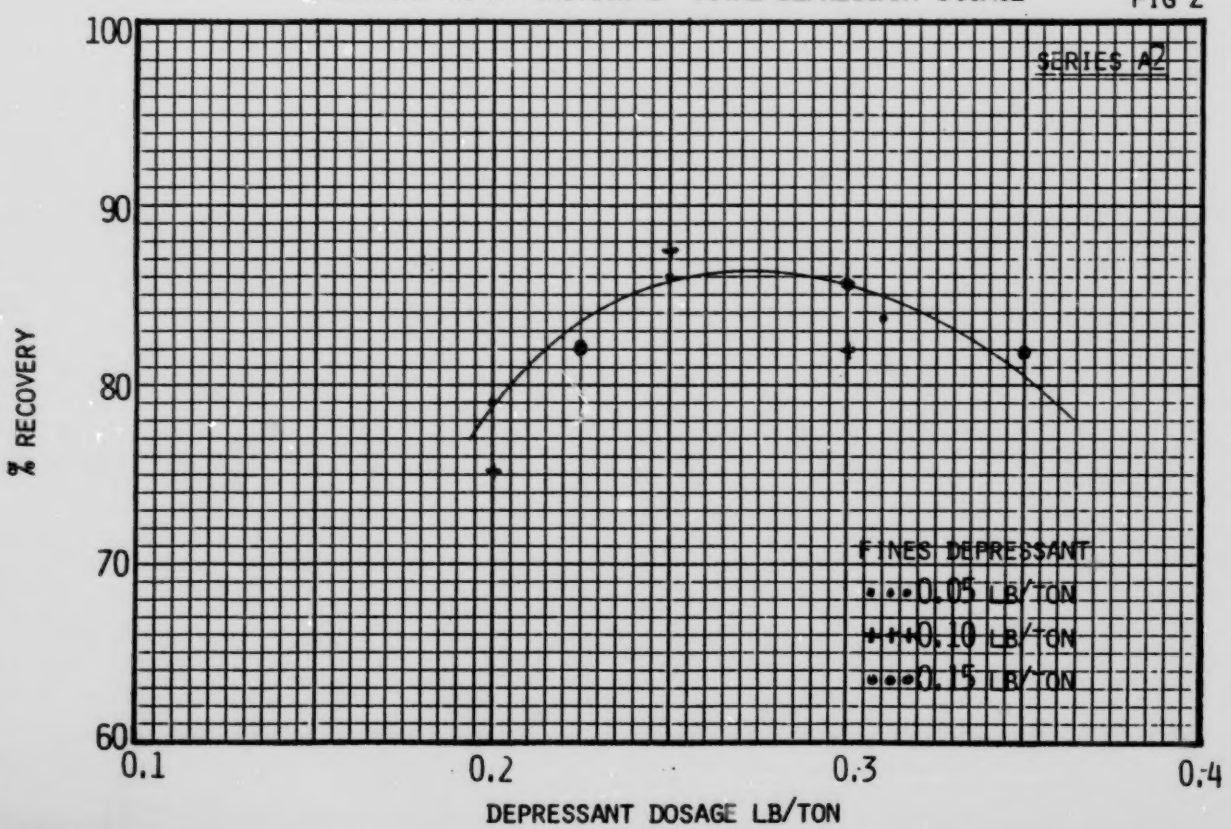
v In Series A1 and A2, the best flotation recovery was achieved at high depressant addition rates to the fines fraction, whereas in Series A3 and A4, a lower rate gave good results.

vi During the course of the tests it was discovered that in Series A1 and A2 the material reporting to fines conditioning was 25% less than in A3 and A4 due to the difference in screening efficiency between wet and dry sizing. This in turn resulted in poor desliming of Series A1 and A2 fines as the desliming procedure used tends to clean a large sample better than a smaller one. It is also expected that scrubbing of coarse material in the absence of fines (as was the case in Series A4) is much more efficient than scrubbing total mill feed (as occurred in Series A1 and A2). These concerns are reflected in the flowsheet developed for Series B ores.

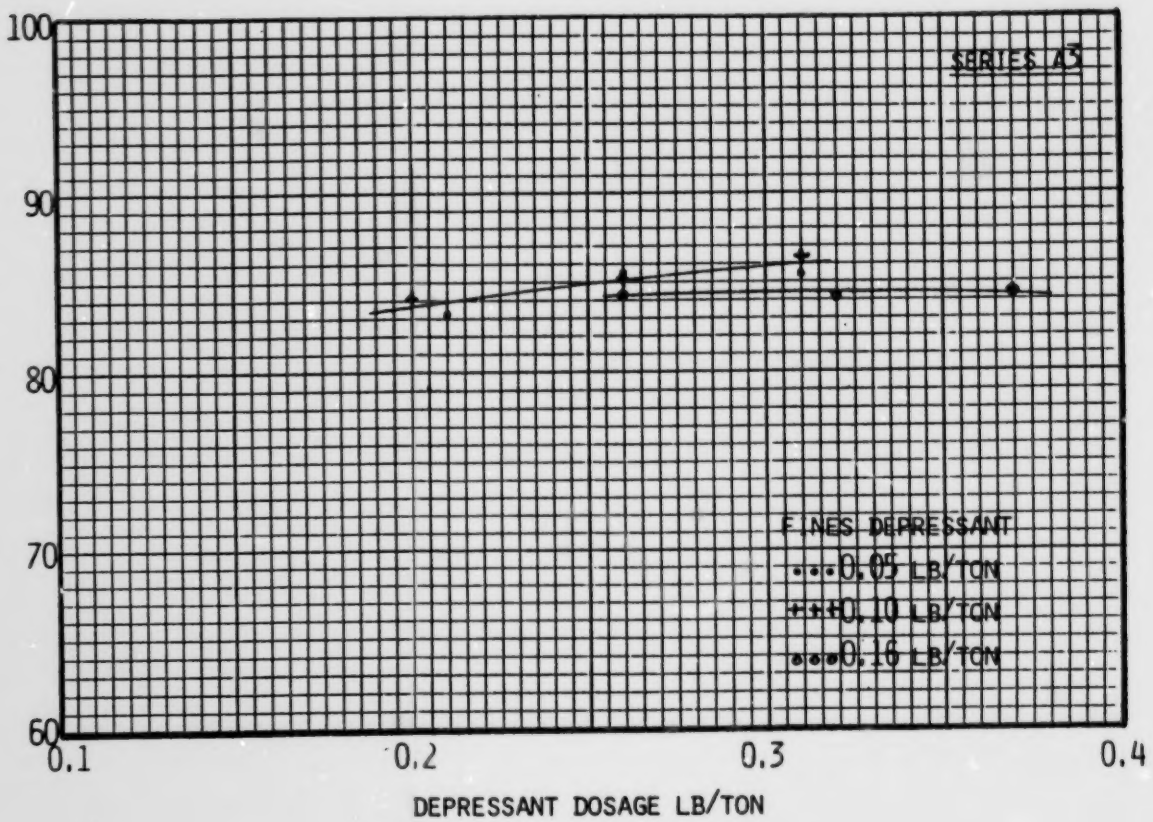
RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 1



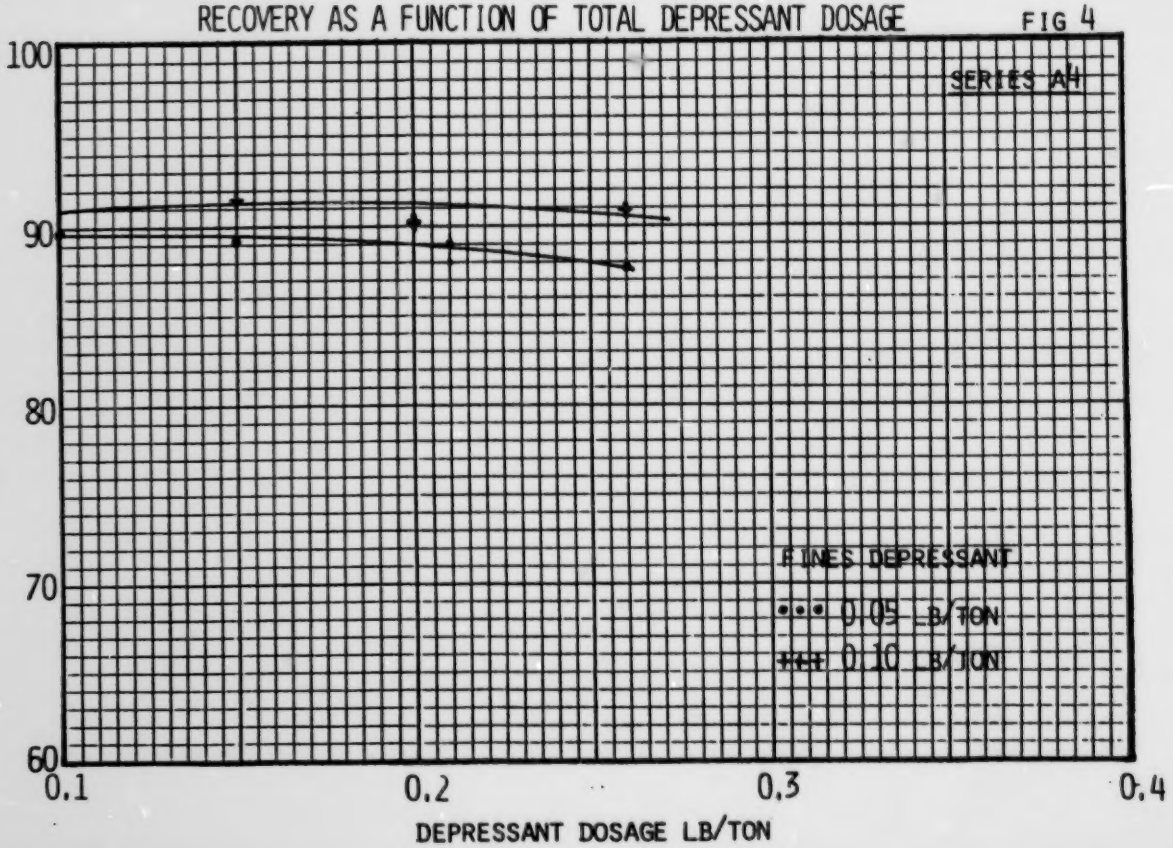
RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 2



RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 3



RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 4



4) Series B Ore Test Work

a) Flowsheet #3 and #4 shows the processing steps established for testing of Series B ores. Flowsheet #4 which incorporates the magnetic separator is identical to Flowsheet #2 used earlier. Flowsheet #3 which uses scrubbing only differs from Flowsheet #1 in that the ore is dry screened at 28 mesh and the oversize is scrubbed separately from the fines. The laboratory procedure for Flowsheets #3 and #4 are given in Appendix 3 and Appendix 5.

b) Table 1 in Appendix 3 gives typical fractional analysis for Series B ore and fractional analysis for a scrubbed fines fraction. The clay content of this ore is similar to Series A while KCl content is slightly higher.

Table 2 in Appendix 3 gives fractional analysis results on coarse feed processed as per Flowsheet #4 and #5, a summary of which is given below.

Mesh Size	Head Ore Sample Wt %	Distribution KCl	WI	Head Ore (slurried in brine) Wt %	Distribution KCl	WI	Head Ore (scrubbed - 2 mins.) Wt %	Distribution KCl	WI
+10	41.7	36.1	54.1	35.7	31.9	12.5	32.3	28.3	10.0
+28	100.0	100.0	100.0	94.4	95.9	40.6	92.3	93.6	25.8

Mesh Size	Head Ore (non-mags) Wt %	Distribution KCl	WI	Head Ore non-mags (slurried in brine) Wt %	Distribution KCl	WI	Head Ore non-mags (scrubbed - 2 mins.) Wt %	Distribution KCl	WI
+10	34.0	30.3	13.5	32.1	28.2	7.4	32.9	28.3	6.5
+28	89.4	91.4	22.2	87.8	89.2	13.3	87.7	89.2	11.2

The following points are evident from the table:

i All clay removal processes reduce the +10 mesh fraction in the ore by about 8%.
ii Scrubbing does not reduce the KCl distribution of the +10 mesh material any more than magnetic separation.
iii Magnetic separation on its own was only slightly better than scrubbing and desliming for coarse clay removal.
iv Magnetic separation in combination with scrubbing and desliming was significantly better at coarse clay removal but KCl losses were significantly higher than with scrubbing and desliming alone.

c) Results of heavy liquid separation of the magnetic fraction is given in Appendix 3, Table 3.

The tests conducted at two liquid specific gravities shows that 65% of the KCl in the magnetics assays 75% KCl and 5% WI. Most of the KCl is in the -14 mesh fraction. About 97% of the clay in the magnetic fraction is combined with 35% of the KCl.

d) The results of reprocessing the magnetic fraction are given in Table 4 of Appendix 3. This involves sizing the magnetics at 14 mesh and reprocessing each fraction on the Permroll with different settings. About 30% of the KCl was recovered from the -14 mesh with 3% of the WI. The +14 mesh non-magnetics contained too much clay to be recovered.

e) Variables tested in each series of flotation tests:

Series B1: Flowsheet #3 with coarse ore fraction processed as follows:

i As is.
ii Slurried and deslimed without scrubbing.
iii Scrubbed 0.5 minutes and deslimed.
iv Scrubbed 1.0 minute and deslimed.

Series B2: Flowsheet #4 with non-magnetics processed as follows:

i As is.
ii Slurried and deslimed without scrubbing.
iii Scrubbed 0.5 minutes and deslimed.
iv Scrubbed 1.0 minute and deslimed.

Series B3:

i Flowsheet #3 - coarse fraction scrubbed for 0.5 minutes.
ii Flowsheet #4 - non-magnetics scrubbed for 0.5 minutes.

Series B4:

i Flowsheet #3 - coarse fraction scrubbed for 0.5 minutes.
ii Flowsheet #3 - coarse fraction scrubbed for 1.0 minute.
iii Flowsheet #4 - non-magnetics slurried and deslimed without scrubbing

In Series B1 and B2, the depressant dosage to coarse was varied. In Series B3 and B4, the total collector dosage was varied.

Data on flotation feed preparation losses and flotation test results are given in Appendix 3, Tables 5-12. A summary of these results are given below. Graphical presentation of results follow in Figures 5-8.

		Flotation Feed			Optimum Flotation Results	
		Assay	Distribution		Recovery	Total Depressant
Series	Test No.	WI	KCl	WI	%	lb./ton
B1	1.xx	4.1	92.5	76.7	61	0.30
	2.xx	2.0	90.4	35.9	87	0.27
	3.xx	1.2	90.0	22.7	90	0.27
	4.xx	1.0	89.5	18.5	91	0.27
B2	5.xx	1.9	87.7	33.5	84	0.26
	6.xx	1.1	86.6	20.6	88	0.17
	7.xx	1.2	86.2	21.8	88	0.17
	8.xx	0.9	86.2	16.8	90	0.17
						Total Collector lb./ton
B3	9.xx	1.1	89.2	20.1	90	0.14
	10.xx	0.7	86.5	13.0	90	0.14
B4	11.xx	1.0	90.3	18.4	90	0.15
	12.xx	0.9	89.9	16.2	90	0.15
	13.xx	0.9	87.1	15.7	90	0.15

The following are evident from these results:

i Scrubbing and desliming removed about 80% of the WI in the ore with a KCl loss of about 10%. About 7% of the KCl was lost in fines desliming.

ii Magnetic separation combined with scrubbing and desliming removed about 85% of the WI in the ore with a KCl loss of about 14%. About 7% of the KCl was lost in fines desliming, about 5% in the magnetic fraction and a further 2% in scrubbing and desliming the non-magnetics.

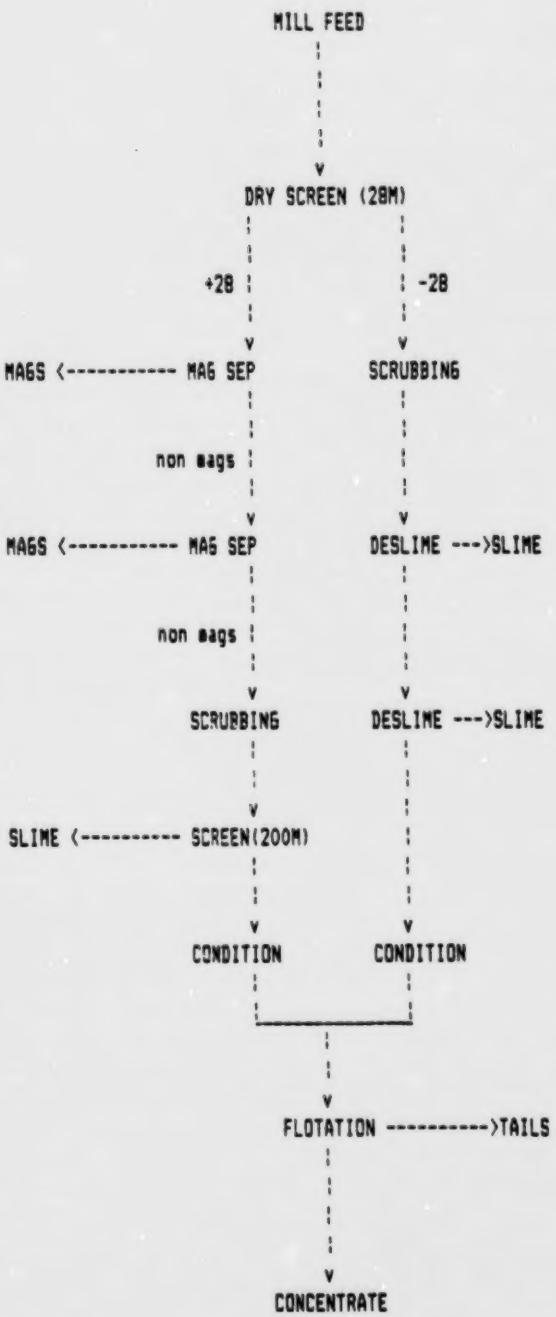
iii The best flotation recoveries were achieved when magnetic separation and scrub-deslime was combined in feed preparation. Recoveries invariably increased with scrubbing time for all tests. Magnetic separation alone does not give good flotation recoveries.

iv With magnetic separation and scrubbing combined, depressant usage can be reduced by about 40% from the levels used for scrub-deslime only. Only marginal savings are apparent in total collector usage by incorporation of magnetic separation into the scrub-deslime circuit.

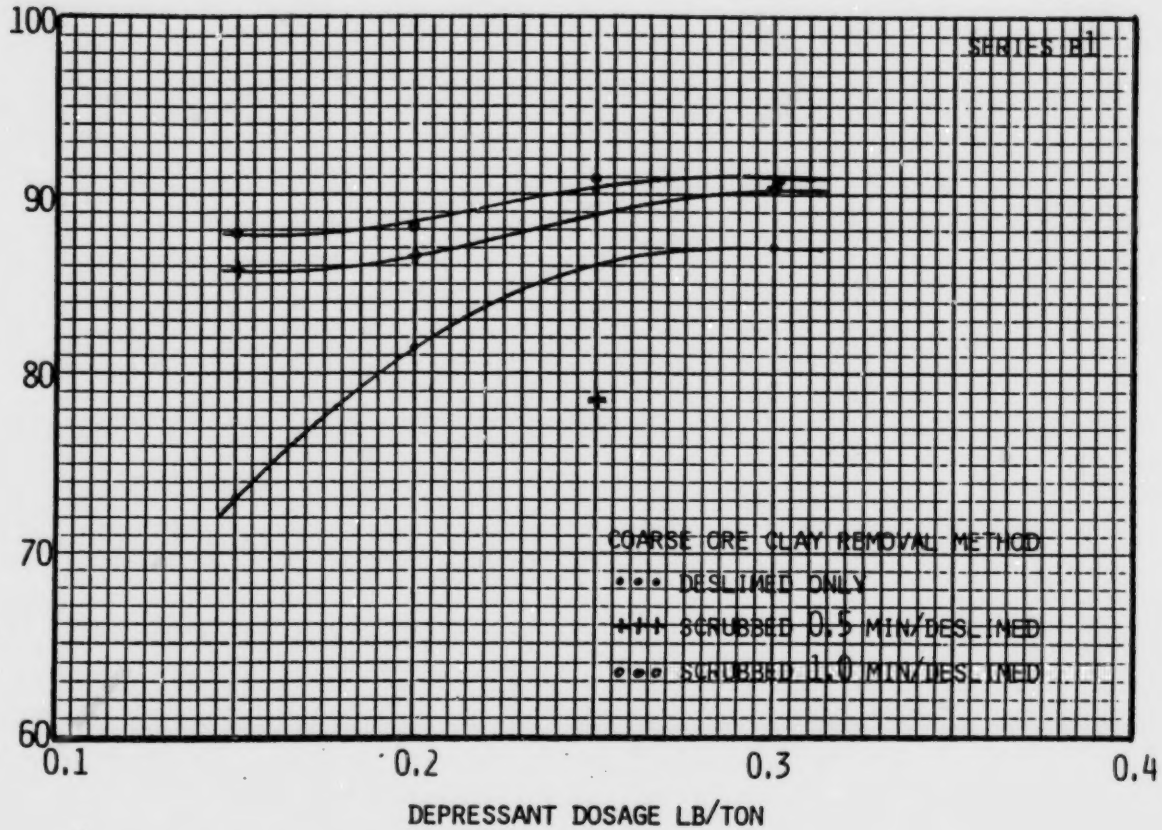
v Ultimate (maximum) flotation recoveries are 1-2% higher with magnetic separation and scrub-deslime combined than with scrub deslime alone.

FLOW SHEET WITH SCREENING PLANT PRIOR TO SCRUBBING
FLOW SHEET #3

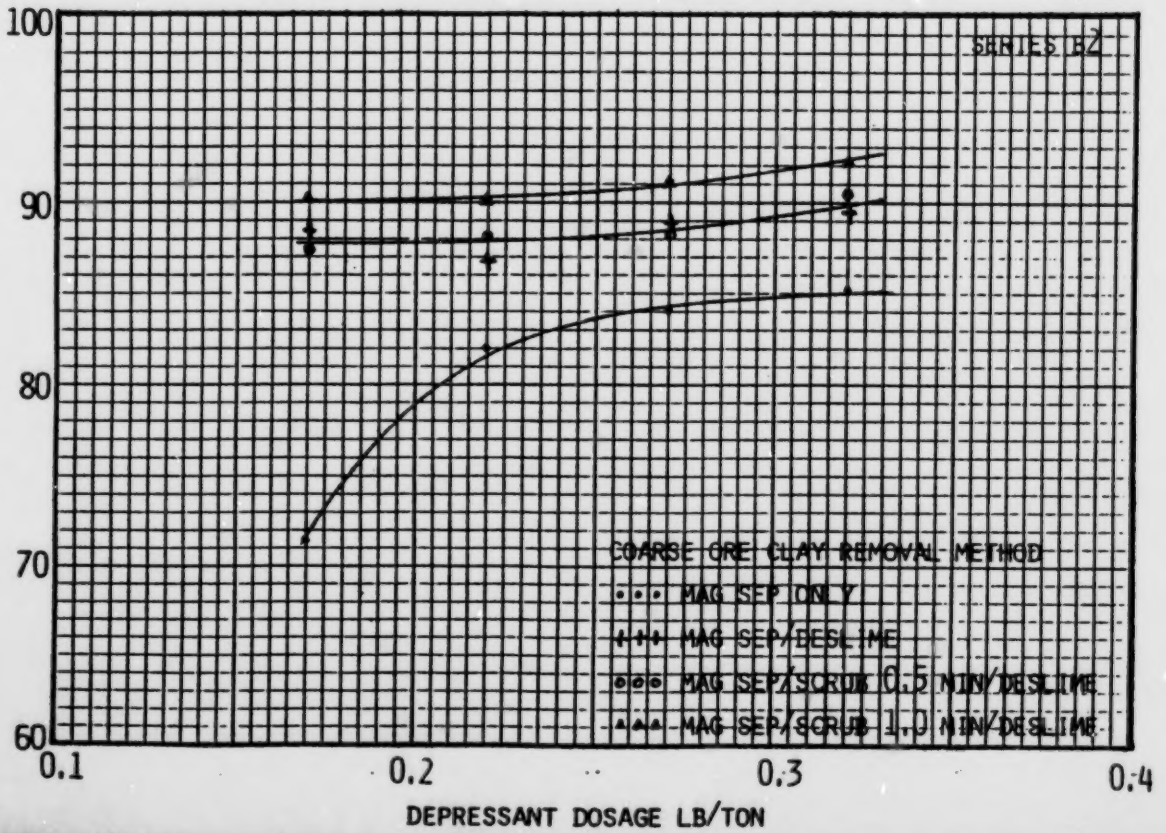
FLOW SHEET INCORPORATING A MAGNETIC SEPERATOR
FLOW SHEET #4



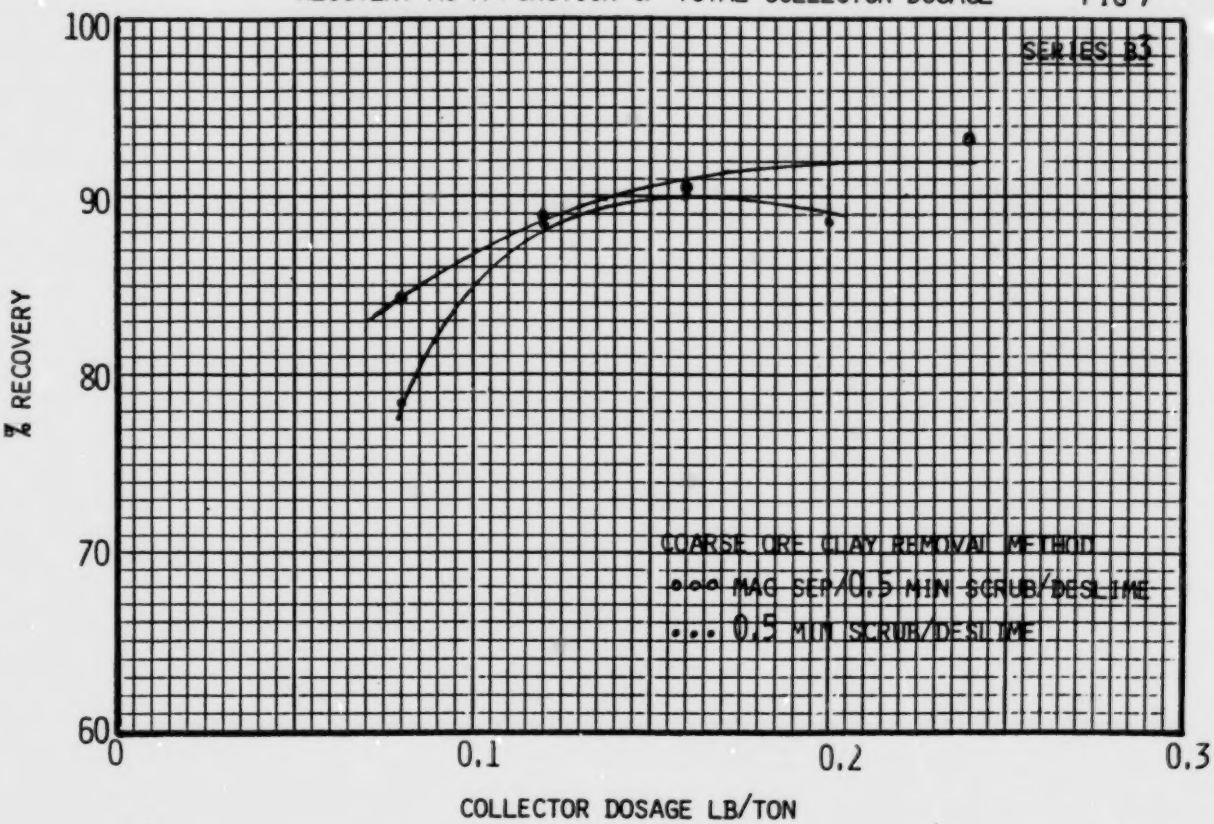
RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 5



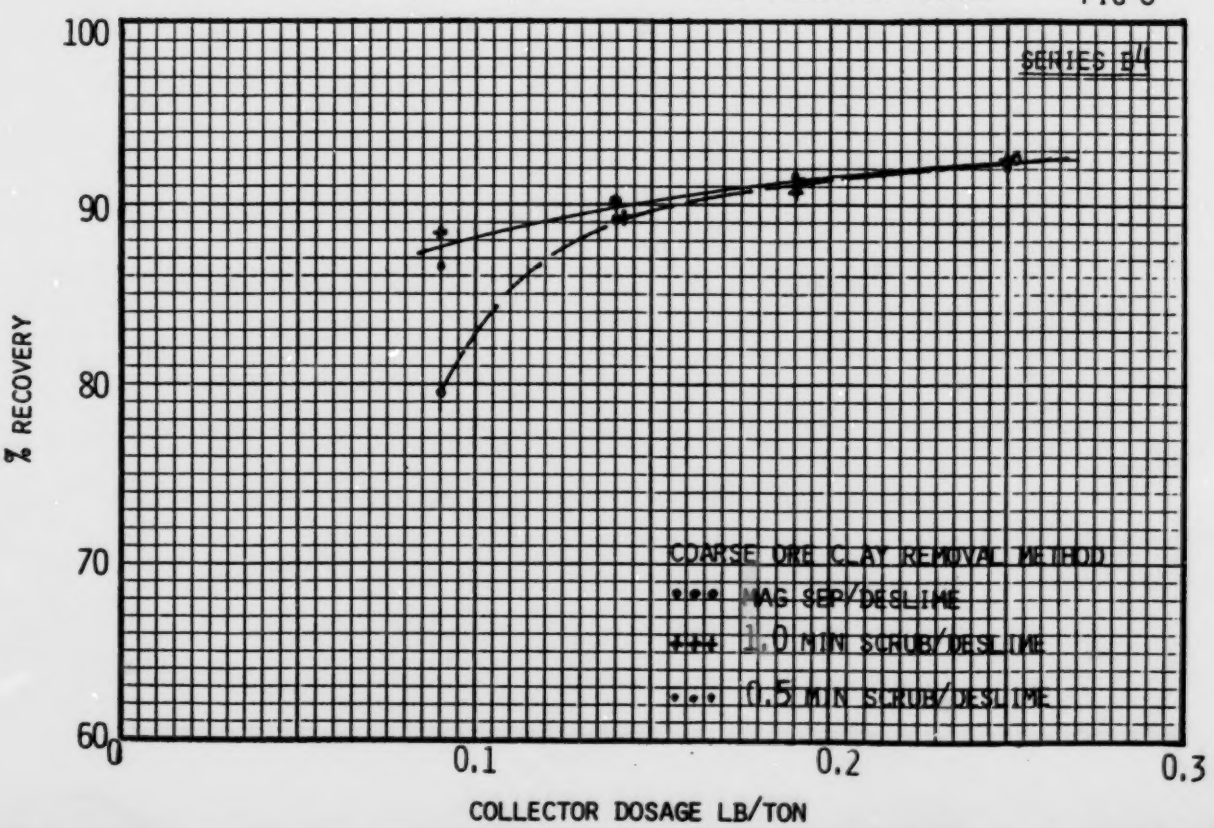
RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 6



RECOVERY AS A FUNCTION OF TOTAL COLLECTOR DOSAGE FIG 7



RECOVERY AS A FUNCTION OF TOTAL COLLECTOR DOSAGE FIG 8



5) Series C Ore Test Work

a) Flowsheets #5 and #6 show the processing steps established for testing of Series C ores. Flowsheet #5 is similar to Flowsheet #1 except for fines desliming which is achieved here through screening at 200 mesh. This procedure gives a fines WI assay of 0.9 - 1.0% as opposed to the 1.5% WI content of the fines deslimed by the decantation procedure used in previous tests. Flowsheet #6 includes reprocessing of the magnetic reject on the Permroll to improve KCl recovery. Scrubbing and desliming is identical for Flowsheets #5 and #6. The laboratory procedure for Flowsheets #5 and #6 are given in Appendix 4 and Appendix 5.

b) Table 1 in Appendix 4 gives typical fractional analysis for Series C ores. The clay content of this ore is lower and the KCl content higher than in Series A and B.

c) Table 2 in Appendix 4 gives typical data on the various magnetic fractions. Reprocessing the -14 mesh magnetics resulted in KCl losses being reduced from 5.4% to 3.7% of the feed. The final magnetic reject assayed 28.5% KCl and 41.3% WI.

d) Variables tested in each series of flotation were as follows:

Series C1: Flowsheet #5 with a 3 minute scrubbing time.

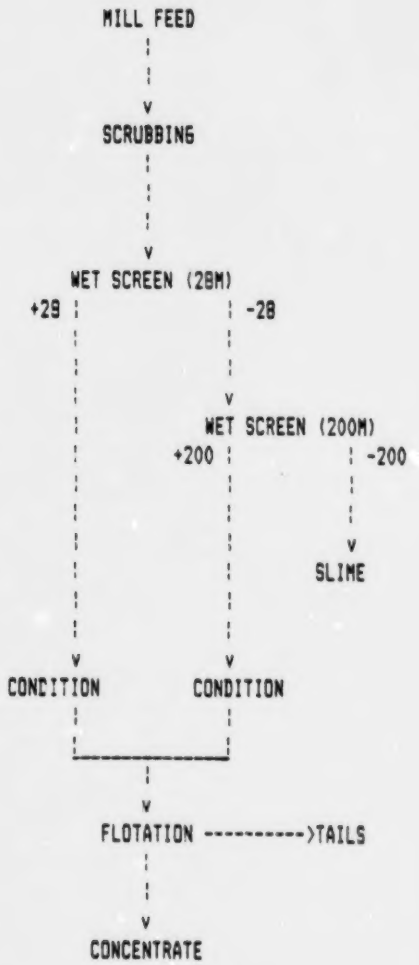
Series C2: i Flowsheet #5 with a 1 minute scrubbing time.
ii Flowsheet #5 with a 2 minute scrubbing time.
iii Flowsheet #5 with a 3 minute scrubbing time.

Series C3: i Flowsheet #6 with a 0.5 minute scrubbing time.
ii Flowsheet #6 with a 1.0 minute scrubbing time.

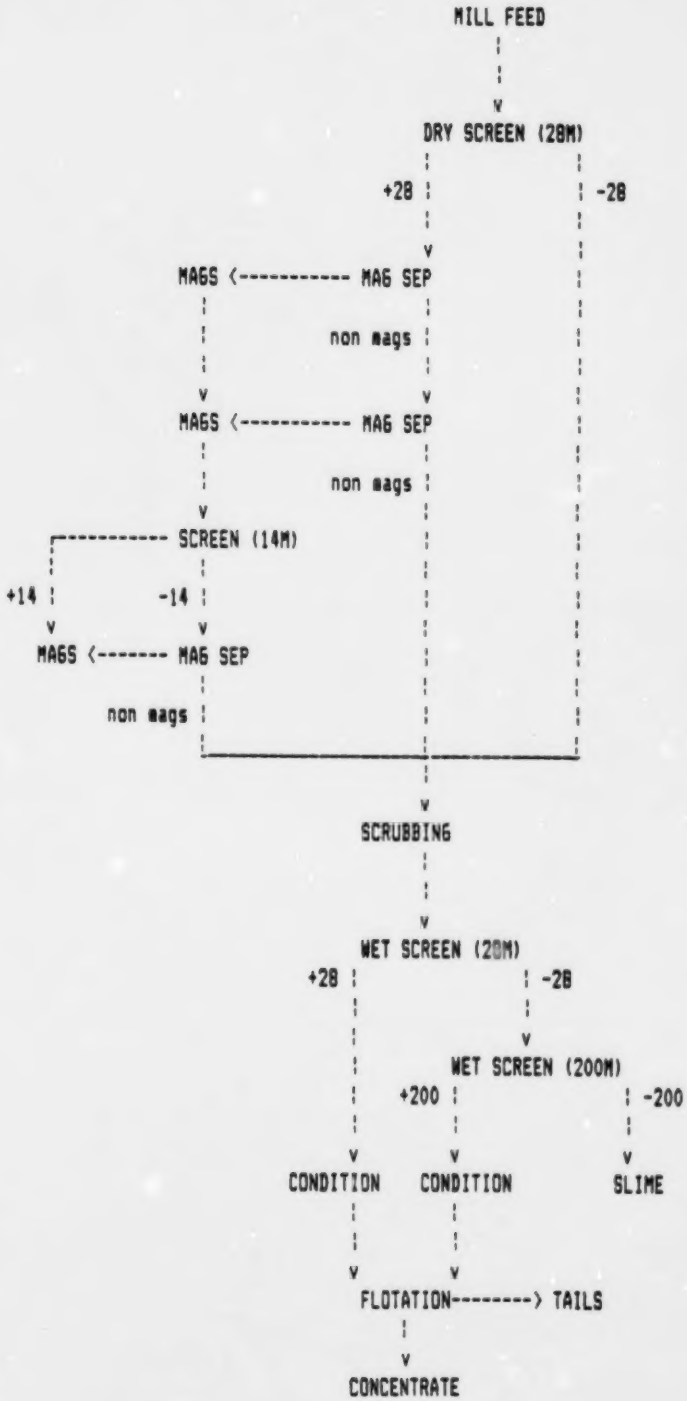
Series C4: i Flowsheet #5 with a 2.0 minute scrubbing time.
ii Flowsheet #6 with a 1.0 minute scrubbing time.

In Series C1 and C3, the coarse and fines depressant dosage was varied.
In Series C2, the coarse depressant dosage was varied.
In Series C4, the total collector dosage was varied.

FLOW SHEET WITH SCRUBBING AND DESLIMING
FLOW SHEET #5



FLOW SHEET INCORPORATING A MAGNETIC SEPERATOR
FLOW SHEET #6



Data on flotation feed preparation losses and flotation test results are given in Appendix 4, Tables 3-10. Results are summarized below. Graphical presentation of results follow in Figures 9-12.

Series	Test No.	Flotation Feed Assay WI	Flotation Feed Distribution KCl	Flotation Feed Distribution WI	Optimum Flotation Results Recovery %	Optimum Flotation Results Total Depressant lb./ton
C1	1.xx	0.7	87.9	15.0	88	0.15
C2	2.xx	0.8	88.8	16.8	89	0.2
	3.xx	0.5	87.2	10.4	90	0.1
	4.xx	0.6	86.2	12.4	90	0.1
C3	5.xx	0.4	86.5	7.9	88	0.15
	6.xx	0.4	85.8	7.5	89	0.15
						Total Collector lb./ton
C4	7.xx	0.6	86.7	13.7	88	0.18
	8.xx	0.4	86.8	8.0	86	0.18

The results indicate the following points:

i Scrubbing and desliming removed about 87% of the WI in the ore with a KCl loss of about 13%.

ii Magnetic separation followed by scrubbing and desliming removed about 92% of the WI in the ore with a KCl loss of about 14%.

iii The WI content of the flotation feed averaged about 0.5% for Series C which is very low in comparison to normal flotation practice.

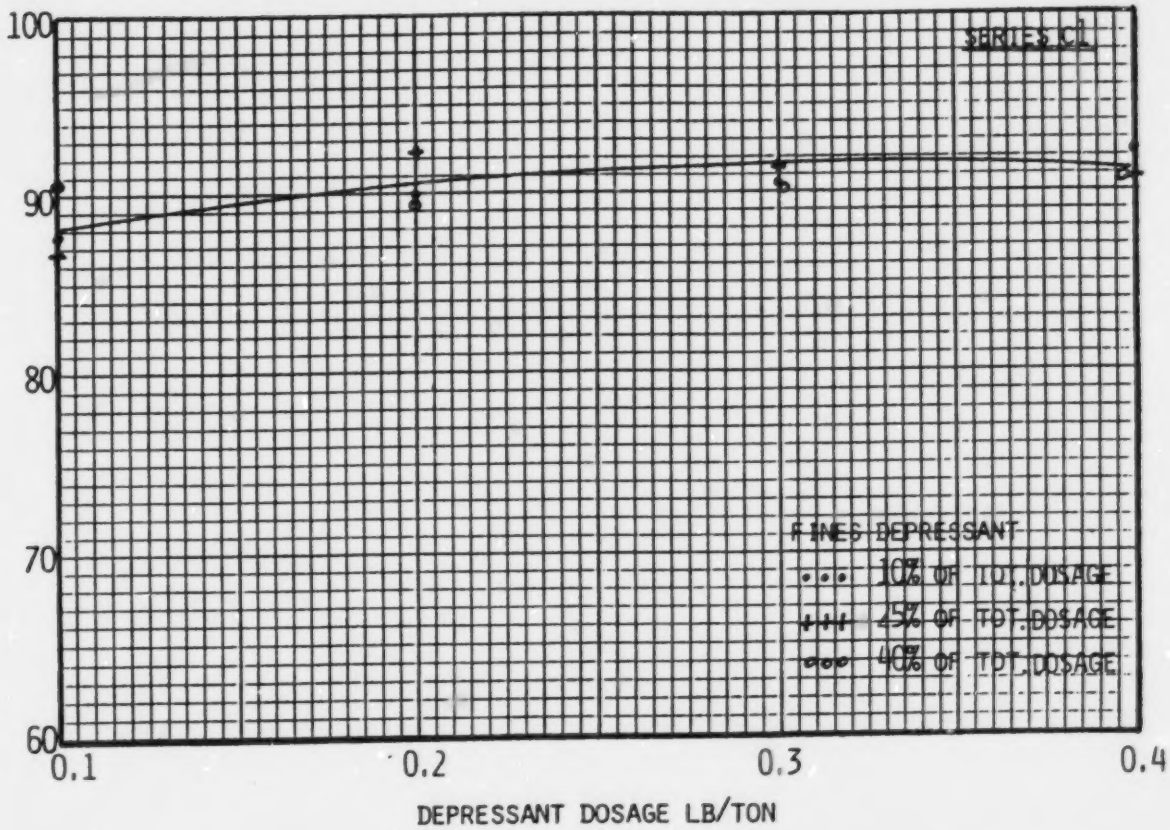
iv In Series C1, the fines depressant rate had little bearing on recovery. This is probably due to the fact that the fines were much cleaner than in Series A or B.

v In Series C2, a scrubbing time of 2 minutes proved to the the optimum for maximum flotation recovery.

vi In Series C3 and C4 with magnetic separation and scrub-deslime combined, the recoveries were slightly less than for scrub-deslime alone. This could be due to some factor in this flowsheet or could be due to the fact that the exceptionally low clay levels required different reagent levels from those tested, however, lack of time prevented further testing on these aspects.

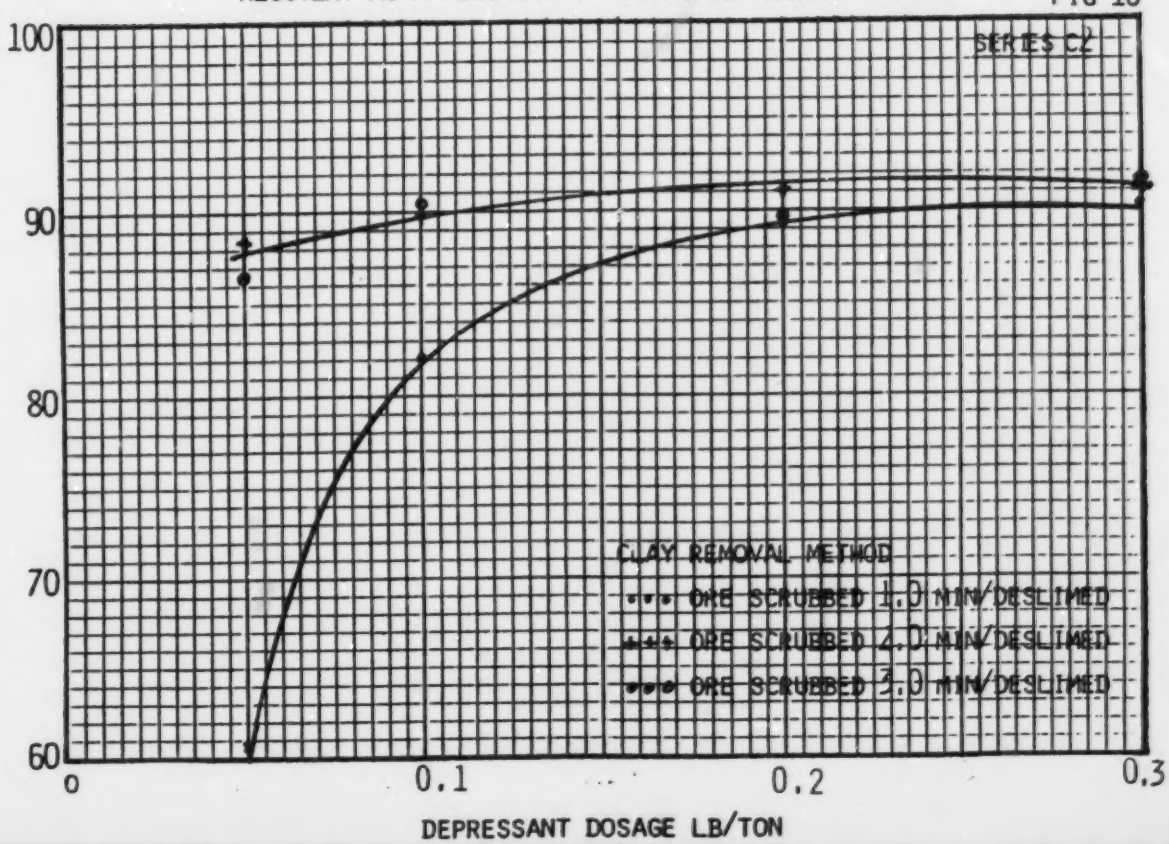
RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE

FIG 9

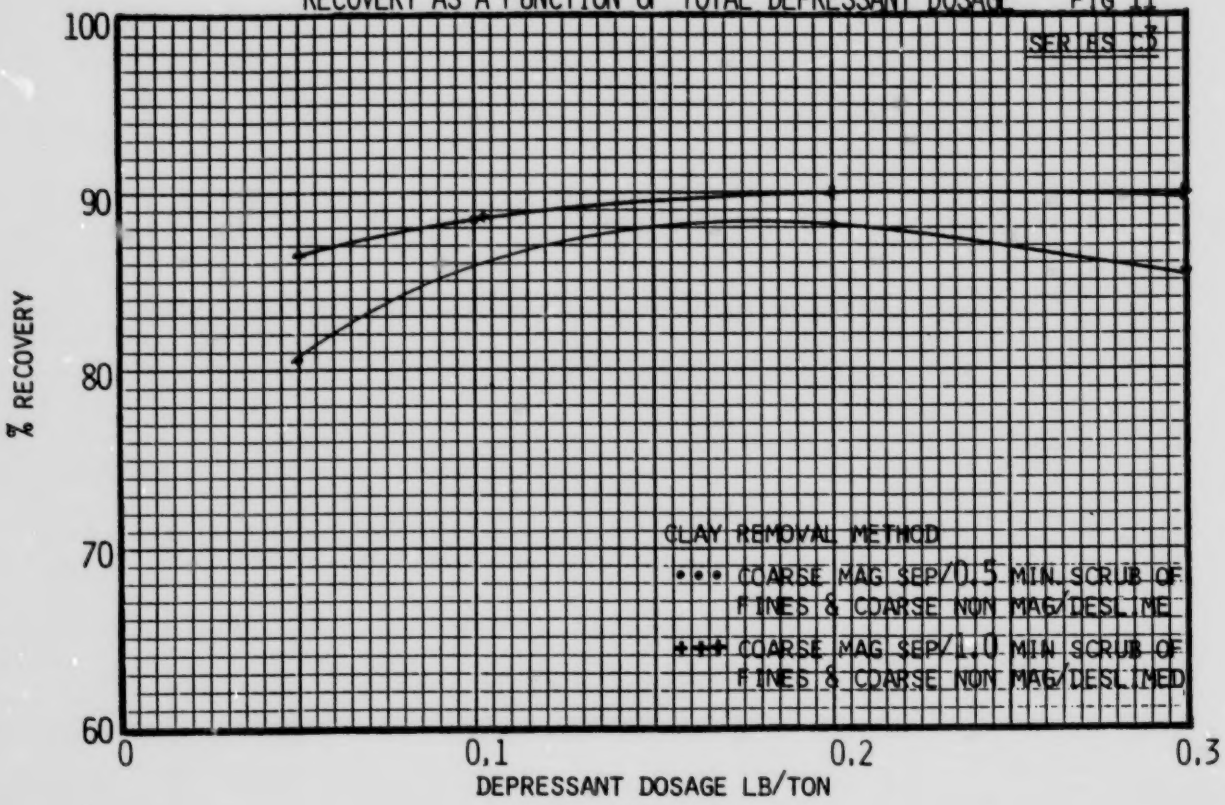


RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE

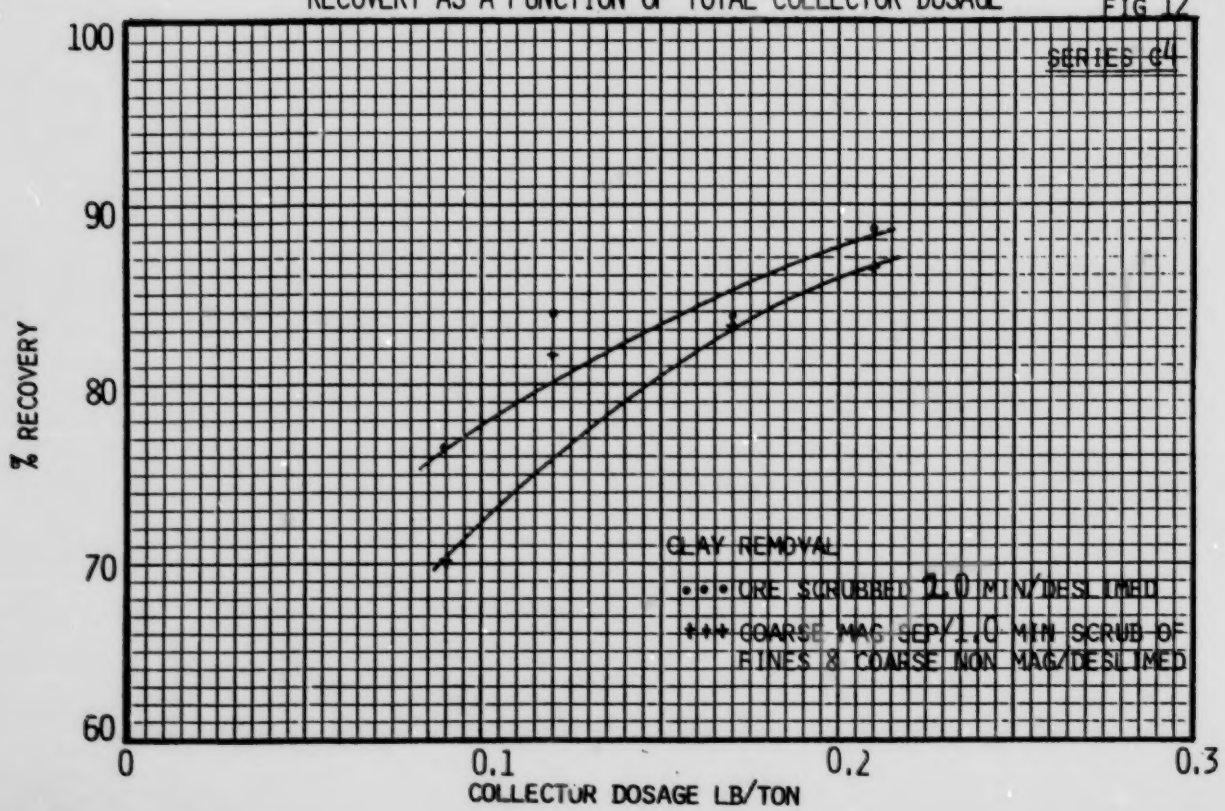
FIG 10



RECOVERY AS A FUNCTION OF TOTAL DEPRESSANT DOSAGE FIG 11



RECOVERY AS A FUNCTION OF TOTAL COLLECTOR DOSAGE FIG 12



Halite Activation

Appendix 6 contains the literature survey regarding magnetic activation of weakly magnetic and non-magnetic materials.

A discussion of the processes which may be applicable to Halite Activation and a list of references are also included.

No bench scale testing of these processes was attempted due to lack of time.

REFERENCES

1. Dry Magnetic Separation of Insol from Sylvite and Halite, DSS File Number: 04SQ.23440-6-9119 by W. S. Hrynewich

APPENDIX 1

Laboratory Permroll Technical Data Sheets

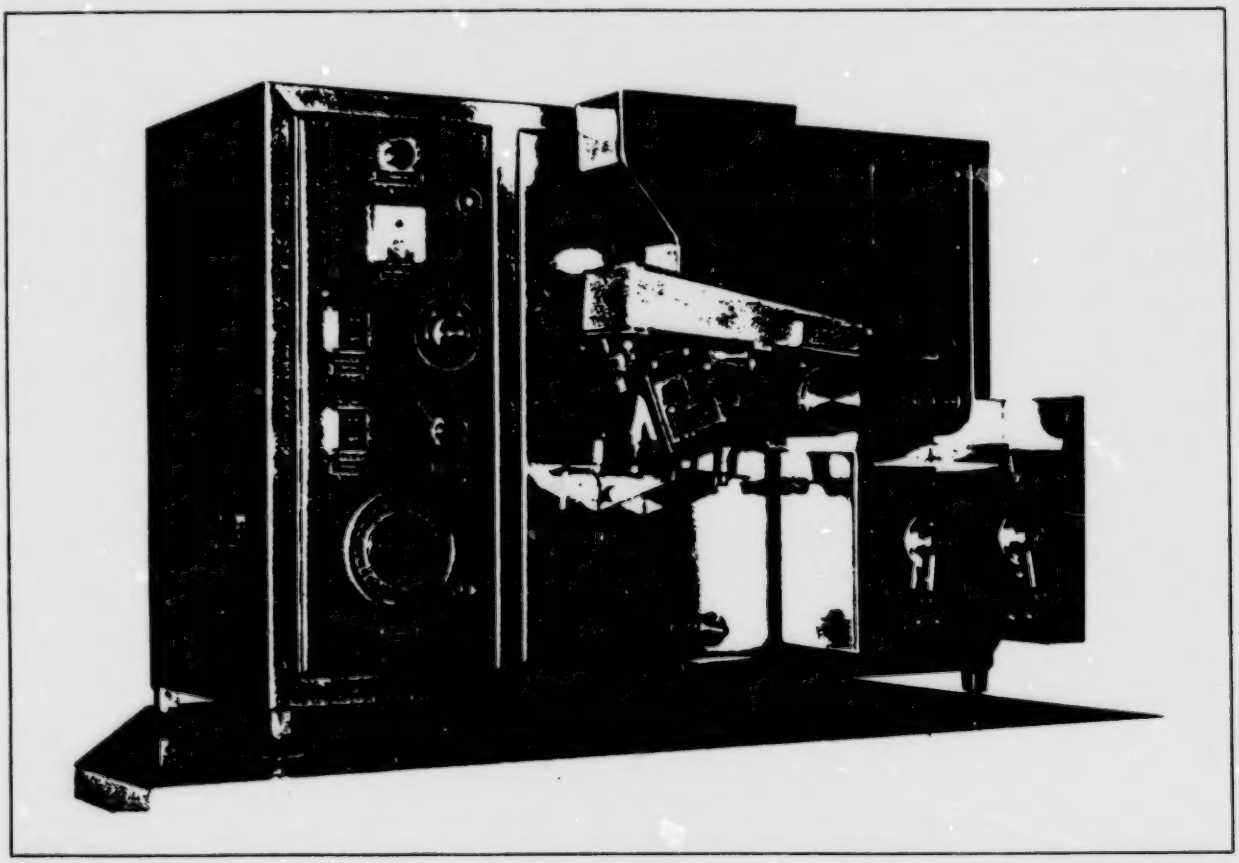
Preparation of Permroll Feed

Permroll Settings

TABLE 1 Effect of Clay Particle Size on Permroll Separation

Laboratory PERMROLL® magnetic separator

Ore Sorters



The high-intensity, high-gradient, permanent magnet roll separator for processing weakly magnetic minerals, the most efficient way.

Introduction

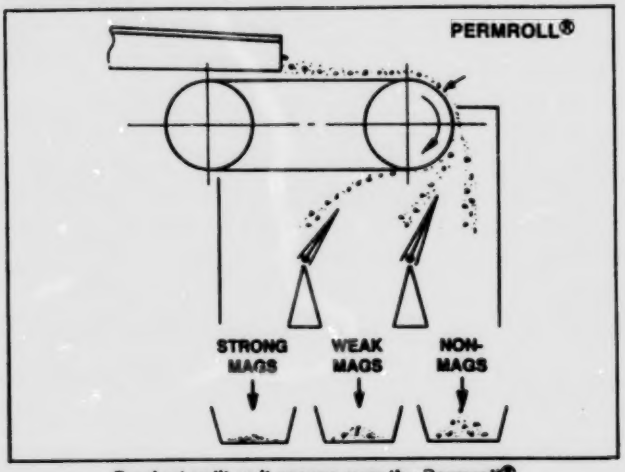
By using new high-energy-product permanent magnetic materials in a proprietary configuration, the PERMROLL® magnetic separator, based on Dr I Yaniv's initial idea, can be designed to generate magnetic attraction-forces for processing anything from ferromagnetic to very weakly paramagnetic minerals. This results in more efficient separation than any existing roll separator. In fact, the strongest PERMROLL® exerts forces exceeding those of any electromagnetic induced roll separator and this is achieved without an air gap.

Operating Principle

The machine is a self-contained bench top unit *(shown overleaf)*.

External to the machine casing is a short belt conveyor which has the PERMROLL® magnet as its head pulley. Material to be separated is fed onto the moving conveyor via a feed hopper and vibro-feeder. As material is conveyed over the PERMROLL® ferromagnetic and paramagnetic particles adhere to the conveyor belt while non-magnetic particles stream freely off the end of the conveyor.

Arranged below the conveyor is a hopper which collects the discharging material and by means of two adjustable splitter blades the different fractions are diverted into collection pans placed beneath the hopper. *(As shown below).*



Product split as it passes over the Permroll®

Application

The PERMROLL® separator can accomplish virtually anything a conventional Induced Magnetic Roll (IMR) separator can, but at lower overall cost. Unlike IMR's the PERMROLL® is not limited by a gap through which particles must pass. This enables the PERMROLL® to successfully separate coarse particles which has not been possible in the past.

No power is required to energise the magnet roll.

Proven dry process applications include minerals from –45 microns (–325 mesh) up to 25 mm particle size with magnetics removal of up to 80 percent by weight.

Examples

Typical examples are:

- Andalusite and pyrophylite beneficiation
- Bauxite cleaning
- Beach sand beneficiation
- Iron ore beneficiation
- Glass raw material cleaning
- Kyanite cleaning
- Diamond beneficiation
- Metal value recovery from wastes
- Limestone and dolomite cleaning
- Magnesite beneficiation
- Wollastonite beneficiation
- Glass sands benefication
- Feldspar
- Quartz cleaning
- Flintclay beneficiation
- High-purity quartz cleaning
- Refactory raw material cleaning
- Graphite upgrading
- Ceramic raw material cleaning
- Diatomaceous earth cleaning

General Description

The laboratory PERMROLL® separator is a high intensity, high gradient dry magnetic separator, designed as a research/development tool, capable of separating a variety of minerals under laboratory conditions.

The machine is equipped with a 100 mm magnetic length PERMROLL® available in different magnetic strengths and diameters identical to the rolls used on the industrial scale PRODUCTION PERMROLL® SEPARATORS* which have been successfully introduced into the mining industry.

Advantages

In comparison with electromagnetic induced roll separators, the PERMROLL® separator has the following advantages:

- Low Installation Cost
- Low Operating Cost
- Low Maintenance Cost

Standard roll as supplied 71 mm dia. 1.[illegible] tesla rating.

Features

The machine comprises the following features:-

- Two litre capacity feed hopper equipped with an adjustable skirt to regulate product outflow depending upon particle size.
- Variable rate vibratory feeder.
- Product conveyor belt with driven PERMROLL® head pulley and stainless steel idler roll.
- Conveyor belt tensioning/tracking controls readily accessible on the outer casing faces.
- Discharge hopper equipped with two easily adjustable splitter blades.
- Variable speed D.C. geared motor drive adjustable from 20 to 350 r.p.m.

Specifications

Power Supply:

220V – 50 Hz or 110V – 60 Hz versions available.

Machine Weight:
106 kg. net.

Principle Dimensions:

Length	910 mm
Height	670 mm
Depth	600 mm

**Production machines are equipped with a PERMROLL® of 1.0 metre effective magnetic length. They are of modular design enabling modules to be stacked one upon the other to form multi-pass machines in a cascade configuration.*

For further details please contact:

ORE SORTERS (NORTH AMERICA) INC.

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Lakewood, Co 80226 USA.
Telephone: 303 985-0138
Twx: 910-937-0374 (Answerback: Engrs. Lkwd)

PREPARATION OF PERMROLL FEED

The Permroll performs poorly if mill feed is passed over the roll before removal of fines. Various mesh sizes of mill feed were used to determine a suitable cutoff size for Permroll feed.

The results of this preliminary test work indicated the following:

1. Best results in terms of clay removal and potash recovery are obtained from the magnetic separator for closely sized feed material.

2. When there was a wide distribution of feed sizes, the finer particles tend to preferentially report to the magnetic fraction.

3. When dealing with feed size of 48 mesh and smaller, the clay separation becomes poor and the feed rate has to be very low, even for closely sized fractions. (See Table 1)

4. When dealing with feed sizes of 150 mesh and smaller, virtually no clay separation is achieved. (See Table 1)

5. Other factors independent of the Permroll are as follow:

   a) A screen separation on dry ore becomes very difficult at fine mesh sizes.

   b) Flotation practice requires that coarse ore be separated from the fines prior to conditions.

It was decided to restrict the Permroll feed to a 6 x 28 mesh fraction for the above reasons.

PERMROLL SETTINGS

The five operating controls for the Permroll were fixed as follows for all tests:

Roll Speed (RPM)	101
Feeder Vibration	6.5
Feed Gate Position	Fixed Position on Frame
Splitter Gate Position	Fixed Position on Frame
Feed Belt Thickness	0.005"

These settings allowed a feed rate of 0.42 tons per hour and gave a non-magnetic product containing a maximum of 2% WI with two passes over the Permroll.

NOTE: The fixed settings were determined from past experience and additional preliminary tests done on the new machine.

TABLE 1

EFFECT OF CLAY PARTICLE SIZE ON PERMROLL CLAY SEPARATION

MESH SIZE	PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
6x10	NON MAG	86.9	32.8	1.3	28.5	1.1	90.8	24.9
	MAG	13.1	22.1	26.0	2.9	3.4	9.2	75.1
	HEAD	100.0	31.4	4.5	31.4	4.5	100.0	100.0
14X28	NON MAG	87.9	38.9	1.0	34.2	0.9	89.0	27.2
	MAG	12.1	35.0	19.4	4.2	2.3	11.0	72.8
	HEAD	100.0	38.4	3.2	38.4	3.2	100.0	100.0
35	NON MAG	92.7	43.3	1.2	40.1	1.1	95.3	35.2
	MAG	7.3	27.4	28.0	2.0	2.0	4.7	64.8
	HEAD	100.0	42.1	3.2	42.1	3.2	100.0	100.0
48	NON MAG	94.2	43.7	2.0	41.2	1.9	96.3	53.1
	MAG	5.8	27.6	28.7	1.6	1.7	3.7	46.9
	HEAD	100.0	42.8	3.5	42.8	3.5	100.0	100.0
65	NON MAG	94.4	43.4	2.3	41.0	2.2	96.4	56.9
	MAG	5.6	27.3	29.4	1.5	1.6	3.6	43.1
	HEAD	100.0	42.5	3.8	42.5	3.8	100.0	100.0
100	NON MAG	95.4	42.0	2.8	40.1	2.7	97.3	65.8
	MAG	4.6	24.2	30.2	1.1	1.4	2.7	34.2
	HEAD	100.0	41.2	4.1	41.2	4.1	100.0	100.0
150x200	NON MAG	96.3	39.6	3.8	38.1	3.7	97.0	86.2
	MAG	3.7	32.4	15.8	1.2	0.6	3.0	13.8
	HEAD	100.0	39.3	4.2	39.3	4.2	100.0	100.0

Note:Feed rate and splitter gate setting were adjusted for each fraction to get the best seperation.The -65 mesh material was passed over the roll three times to make the seperation - material collected adhered to the belt until the idler pulley was reached.

APPENDIX 2

Test Work on Series A Ores

Laboratory Procedure for Flowsheet #1

Laboratory Procedure for Flowsheet #2

Table 1	Fractional Analysis of Head Ore, Scrubbed Ore and Non-Mags
Table 2	Fractional Analysis and Heavy Liquid Separation of Mag Fraction
Table 3	Losses Incurred in Preparation of Flotation Feed
Table 4	Series A1, Flotation Test Results
Table 5	Series A2, Flotation Test Results
Table 6	Series A3, Flotation Test Results
Table 7	Series A4, Flotation Test Results

LABORATORY PROCEDURE FOR FLOWSHEET #1

1. Split head ore into 800 gm lots for processing as follows.

2. Scrub for 3 minutes at 900 rpm on Denver Scrubber with 300 mls of brine at 68% solids.

3. Wet screen sample at 28 mesh using only 500 mls of brine.

4. Place oversize in beaker and when solids settle, decant clear brine so that slurry weight is 750 gms (ie 65% solids). Oversize is approximately 525 gms.

5. Place undersize fraction in a 1000 ml graduate cylinder, invert 4 times, settle for 2 minutes and drain to 300 ml level on cylinder through 3/10" hole drilled on cylinder wall.

   Refill cylinder to 1000 ml level with brine, invert 4 times, settle for 1 minute and drain to 300 ml mark.

   Filter slimes collected in both steps, dry, assay and brine correct.

   Place settled solids from cylinder, in a beaker and when brine layer clears, decant to make slurry weight to 300 gms (ie 60% solids). Undersize approximately 175 gms.

6. The oversize from Step 4 and the settled solids from Step 6 are used for conditioning as coarse and fines respectively for flotation tests.

LABORATORY PROCEDURE FOR FLOWSHEET #2

1. Split head ore into 800 gm lots for processing as follows.

2. Screen at 28 mesh. Oversize is about 525 gms.

3. The oversize fraction is passed over the Permroll with variables at standard settings.

   The non-mag fraction is passed over the Permroll a second time.

   The mag fraction is weighed and assayed. Non-mags about 475 gms.

4. The undersize fraction is scrubbed with 450 mls of brine for 1 minute at 900 rpm on the Denver scrubber (ie 33% solids).

   Place slurry in 1000 ml cylinder, make up to 1000 ml level, invert 4 times, settle 2 minutes and drain to 300 ml level through drain hole on cylinder wall.

   Refill cylinder to 1000 ml level with brine, invert 4 times, settle for 1 minute and drain to 300 ml mark.

   Filter slimes collected in both steps, dry, assay and brine correct.

   Place settled solids from cylinder in a beaker and when brine layer clears, decant to make slurry weight to 380 gms (ie 60% solids). Undersize approximately 225 gms.

5. The oversize from Step 3 is slurred with 200 mls of brine (ie 66% solids) for coarse conditioning. The undersize from Step 4 is used for fine conditioning.

6. Alternate to Step 5 (for test runs which required scrubbing-desliming of the non-mags)

   The oversize from Step 3 is slurried with 200 mls of brine (ie 66% solids) and scrubbed for 0.5 to 1.5 minutes (as required) at 900 rpm on the Denver scrubber. The slurry is then screened at 200 mesh using only 500 mls of brine. The -200 mesh is filtered, dried and assayed. The +200 mesh is placed in a beaker and the slurry is made up to 700 gms (ie 66% solids) for coarse conditioning.

TABLE 1

FRACTIONAL ANALYSIS TYPICAL SERIES-A ORES

MESH SIZE	HEAD ORE SAMPLE WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	HEAD ORE (SCRUBBED 3 MINUTES & DESLIMED)‡‡ WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	HEAD ORE(COARSE NON-MAGS & SCRUBBED FINES)‡‡‡ WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
+6	2.0	22.3	9.7	0.4	0.2	1.2	4.2	1.4	27.3	5.0	0.4	0.1	1.1	1.5	1.5	18.4	7.5	0.3	0.1	0.8	2.6
8	11.6	27.5	7.2	3.2	0.8	8.8	18.0	10.0	26.0	2.8	2.6	0.3	7.3	5.9	10.7	28.0	2.9	3.0	0.3	8.6	7.0
10	15.2	33.5	4.7	5.1	0.7	14.0	15.4	14.0	31.3	2.6	4.4	0.4	12.3	7.7	14.0	32.1	1.8	4.5	0.3	12.9	5.7
14	14.3	36.7	3.9	5.2	0.6	14.4	12.0	13.3	35.0	2.0	4.7	0.3	13.0	5.6	13.1	35.2	1.3	4.6	0.2	13.3	3.9
20	10.9	38.3	3.5	4.2	0.4	11.5	8.2	10.6	37.7	1.5	4.0	0.2	11.2	3.4	10.6	36.7	1.2	3.9	0.1	11.2	2.9
28	10.9	41.0	3.1	4.5	0.3	12.3	7.3	10.6	40.6	1.5	4.3	0.2	12.1	3.4	8.8	38.3	1.6	3.4	0.1	9.7	3.2
35	7.4	42.3	3.1	3.1	0.2	8.6	5.0	7.6	40.1	1.6	3.0	0.1	8.5	2.6	7.9	41.4	1.6	3.3	0.1	9.4	2.9
48	7.1	43.6	3.2	3.1	0.2	8.5	4.9	7.4	42.0	1.7	3.1	0.1	8.7	2.7	7.4	41.6	1.9	3.1	0.1	8.9	3.2
65	4.7	42.9	3.1	2.0	0.1	5.5	3.1	4.7	40.9	1.4	1.9	0.1	5.4	1.4	4.8	41.3	2.0	2.0	0.1	5.7	2.2
100	5.2	38.0	4.8	2.0	0.2	5.4	5.4	4.9	38.7	1.6	1.9	0.1	5.3	1.7	4.8	39.7	2.1	1.9	0.1	5.5	2.3
150	2.7	36.3	4.8	1.0	0.1	2.7	2.8	1.8	31.6	2.2	0.6	0.0	1.6	0.8	1.9	38.2	2.1	0.7	0.0	2.1	0.9
200	2.4	35.4	5.0	0.8	0.1	2.3	2.6	1.0	31.5	2.4	0.3	0.0	0.9	0.5	1.2	46.5	3.5	0.6	0.0	1.6	1.0
-200	5.6	30.3	9.1	1.7	0.5	4.7	11.0	0.9	43.2	7.1	0.4	0.1	1.1	1.4	1.3	37.1	2.5	0.5	0.0	1.4	0.7
MAGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	26.5	29.5	1.6	1.8	4.6	40.1
SLIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	35.0	24.7	4.1	2.9	11.6	61.6	6.0	24.7	15.8	1.5	0.9	4.3	21.5
TOTAL	100.0	36.4	4.6	36.4	4.6	100.0	100.0	100.0	35.7	4.7	35.7	4.7	100.0	100.0	100.0	34.7	4.4	34.7	4.4	100.0	100.0

NOTE :‡‡ Series A1 flot. feed (including slime removed in desliming).
‡‡‡Series A3 flot. feed (including magnetics removed from the coarse and slime removed from the fines).

TABLE 2

HEAVY LIQUID SEPARATION OF MAGNETICS FROM SERIES-A COARSE ORE

STREAM	MESH SIZE	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
FLOAT	+6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	1.0	46.0	20.4	0.5	0.2	1.7	0.7
	10	2.9	51.4	16.5	1.5	0.5	5.5	1.6
	14	5.4	51.2	8.7	2.8	0.5	10.2	1.6
	20	8.4	53.2	3.8	4.5	0.3	16.5	1.1
	-20	13.7	52.0	5.8	7.1	0.8	26.2	2.7
	TOTAL	31.4	51.9	7.2	16.3	2.3	60.0	7.7
SINK	+6	1.5	23.2	50.0	0.3	0.8	1.3	2.6
	8	14.0	18.8	43.7	2.6	6.1	9.7	20.8
	10	16.3	16.7	40.0	2.7	6.5	10.0	22.2
	14	14.9	14.6	37.1	2.2	5.5	8.0	18.8
	20	11.8	14.1	36.8	1.7	4.3	6.1	14.8
	-20	10.1	13.2	37.8	1.3	3.8	4.9	13.0
	TOTAL	68.6	15.9	39.5	10.9	27.1	40.0	92.2
HEAD	+6	1.5	23.2	50.0	0.3	0.8	1.3	2.6
	8	15.0	20.6	42.2	3.1	6.3	11.4	21.6
	10	19.2	21.9	36.4	4.2	7.0	15.5	23.8
	14	20.3	24.3	29.6	4.9	6.0	18.2	20.5
	20	20.2	30.4	23.1	6.1	4.7	22.6	15.9
	-20	23.8	35.5	19.4	8.4	4.6	31.1	15.7
	TOTAL	100.0	27.2	29.4	27.2	29.4	100.0	100.0

NOTE: Liquid specific gravity 2.20 for all fractions.

TABLE 3

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
SERIES A 1 : Scrubbing time for ore - 3 minutes.							
FLOT FD	86.7	36.9	1.7	32.0	1.5	87.5	29.6
SLIME	13.3	34.4	26.4	4.6	3.5	12.5	70.4
HEAD	100.0	36.6	5.0	36.6	5.0	100.0	100.0
SERIES A 2 : Scrubbing time for ore - 1.5 minutes.							
FLOT FD	87.0	37.2	1.7	32.4	1.5	87.2	30.6
SLIME	13.0	36.4	25.8	4.7	3.4	12.8	69.4
HEAD	100.0	37.1	4.8	37.1	4.8	100.0	100.0
SERIES A 3 : Coarse ore fraction processed on Permroll, fine ore fraction scrubbed and deslimed.							
FLOT FD	86.0	37.3	1.8	32.1	1.5	89.0	32.4
SLIME-F	7.9	30.4	16.5	2.4	1.3	6.7	27.3
MAGS	6.1	25.6	31.6	1.6	1.9	4.3	40.3
HEAD	100.0	36.0	4.8	36.0	4.8	100.0	100.0
SERIES A 4 : Coarse ore fraction processed on Permroll, then scrubbed for 0.5 minutes and deslimed. Fine ore fraction scrubbed and deslimed.							
FLOT FD	85.0	37.6	1.1	32.0	0.9	88.5	20.5
SLIME-F	7.8	28.5	16.7	2.2	1.3	6.2	28.6
SLIME-C	1.0	33.2	36.5	0.3	0.4	0.9	8.0
MAGS	6.2	25.6	31.6	1.6	2.0	4.4	42.9
HEAD	100.0	36.1	4.6	36.1	4.6	100.0	100.0

Note : Slime - F = Slime from fine ore.
Slime - C = Slime from coarse ore.

TABLE 4

SERIES A1 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
1.01	Conc.	237.3	35.2	87.5	1.4	30.8	0.5	83.6	28.5	0.05	0.16	0.10	0.08	0.17	0.10
	Tails	437.6	64.8	9.3	1.9	6.0	1.2	16.4	71.5						
	Head	674.9	100.0	36.8	1.7	36.8	1.7	100.0	100.0						
1.02	Conc.	235.5	34.3	89.3	1.5	30.6	0.5	83.9	28.1	0.05	0.21	0.10	0.08	0.17	0.10
	Tails	452.0	65.7	8.9	2.0	5.9	1.3	16.1	71.9						
	Head	687.5	100.0	36.4	1.8	36.4	1.8	100.0	100.0						
1.03	Conc.	243.5	36.2	88.9	1.0	32.2	0.4	87.0	24.0	0.05	0.26	0.10	0.08	0.17	0.10
	Tails	429.5	63.8	7.5	1.8	4.8	1.1	13.0	76.0						
	Head	673.0	100.0	37.0	1.5	37.0	1.5	100.0	100.0						
1.04	Conc.	228.8	33.5	90.3	1.7	30.3	0.6	79.3	28.1	0.10	0.10	0.10	0.08	0.17	0.10
	Tails	453.3	66.5	11.9	2.2	7.9	1.5	20.7	71.9						
	Head	682.1	100.0	38.2	2.0	38.2	2.0	100.0	100.0						
1.05	Conc.	238.8	35.2	88.8	1.5	31.3	0.5	85.8	32.4	0.10	0.16	0.10	0.08	0.17	0.10
	Tails	439.5	64.8	8.0	1.7	5.2	1.1	14.2	67.6						
	Head	678.3	100.0	36.4	1.6	36.4	1.6	100.0	100.0						
1.06	Conc.	242.0	35.8	89.9	1.1	32.2	0.4	86.1	26.5	0.10	0.21	0.10	0.08	0.17	0.10
	Tails	434.1	64.2	8.1	1.7	5.2	1.1	13.9	73.5						
	Head	676.1	100.0	37.4	1.5	37.4	1.5	100.0	100.0						
1.07	Conc.	248.6	37.0	88.4	1.4	32.7	0.5	88.7	28.1	0.16	0.10	0.10	0.08	0.17	0.10
	Tails	424.0	63.0	6.6	2.1	4.2	1.3	11.3	71.9						
	Head	672.6	100.0	36.8	1.8	36.8	1.8	100.0	100.0						
1.08	Conc.	248.8	37.3	88.0	1.4	32.8	0.5	89.9	27.5	0.16	0.16	0.10	0.08	0.17	0.10
	Tails	418.3	62.7	5.9	2.2	3.7	1.4	10.1	72.5						
	Head	667.1	100.0	36.5	1.9	36.5	1.9	100.0	100.0						
1.09	Conc.	245.3	36.8	88.1	1.2	32.4	0.4	90.0	28.0	0.16	0.21	0.10	0.08	0.17	0.10
	Tails	420.8	63.2	5.7	1.8	3.6	1.1	10.0	72.0						
	Head	666.1	100.0	36.0	1.6	36.0	1.6	100.0	100.0						

NOTE: 1.Brine temperature :84 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & Armeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 5

SERIES A2 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
2.01	Conc.	228.2	32.6	89.4	1.7	29.2	0.6	78.9	26.4	0.05	0.15	0.10	0.07	0.17	0.10
	Tails	470.9	67.4	11.6	2.3	7.8	1.5	21.1	73.6						
	Head	699.1	100.0	37.0	2.1	37.0	2.1	100.0	100.0						
2.02	Conc.	241.3	34.7	88.2	1.5	30.6	0.5	83.0	32.0	0.05	0.20	0.10	0.07	0.17	0.10
	Tails	453.4	65.3	9.6	1.7	6.3	1.1	17.0	68.0						
	Head	694.7	100.0	36.9	1.6	36.9	1.6	100.0	100.0						
2.03	Conc.	219.6	31.4	89.3	1.7	28.1	0.5	73.8	32.8	0.05	0.26	0.10	0.07	0.17	0.10
	Tails	478.9	68.6	14.5	1.6	9.9	1.1	26.2	67.2						
	Head	698.5	100.0	38.0	1.6	38.0	1.6	100.0	100.0						
2.04	Conc.	226.2	32.6	88.4	1.6	28.8	0.5	75.3	31.3	0.10	0.10	0.10	0.07	0.17	0.10
	Tails	467.6	67.4	14.0	1.7	9.4	1.1	24.7	68.7						
	Head	693.8	100.0	38.3	1.7	38.3	1.7	100.0	100.0						
2.05	Conc.	239.5	34.9	88.9	1.3	31.0	0.5	87.5	31.7	0.10	0.15	0.10	0.07	0.17	0.10
	Tails	446.4	65.1	6.8	1.5	4.4	1.0	12.5	68.3						
	Head	685.9	100.0	35.5	1.4	35.5	1.4	100.0	100.0						
2.06	Conc.	236.0	34.5	89.3	1.3	30.8	0.4	82.0	27.5	0.10	0.20	0.10	0.07	0.17	0.10
	Tails	448.7	65.5	10.3	1.8	6.7	1.2	18.0	72.5						
	Head	684.7	100.0	37.5	1.6	37.5	1.6	100.0	100.0						
2.07	Conc.	240.3	34.6	88.5	1.5	30.7	0.5	82.0	30.6	0.15	0.10	0.10	0.07	0.17	0.10
	Tails	453.3	65.4	10.3	1.8	6.7	1.2	18.0	69.4						
	Head	693.6	100.0	37.4	1.7	37.4	1.7	100.0	100.0						
2.08	Conc.	247.4	35.7	87.8	1.6	31.3	0.6	85.6	31.8	0.15	0.15	0.10	0.07	0.17	0.10
	Tails	446.1	64.3	8.2	1.9	5.3	1.2	14.4	68.2						
	Head	693.5	100.0	36.6	1.8	36.6	1.8	100.0	100.0						
2.09	Conc.	242.3	35.2	87.5	1.6	30.8	0.6	81.8	30.3	0.15	0.20	0.10	0.07	0.17	0.10
	Tails	446.0	64.8	10.6	2.0	6.9	1.3	18.2	69.7						
	Head	688.3	100.0	37.7	1.9	37.7	1.9	100.0	100.0						

NOTE: 1.Brine temperature :81 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & Armeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 6

SERIES A3 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
3.01	Conc.	231.8	34.1	89.5	2.1	30.5	0.7	83.3	30.3	0.05	0.16	0.10	0.07	0.17	0.10
	Tails	447.7	65.9	9.3	2.5	6.1	1.6	16.7	69.7						
	Head	679.5	100.0	36.7	2.4	36.7	2.4	100.0	100.0						
3.02	Conc.	243.2	36.0	87.8	1.5	31.6	0.5	85.6	31.9	0.05	0.21	0.10	0.07	0.17	0.10
	Tails	432.6	64.0	8.3	1.8	5.3	1.2	14.4	68.1						
	Head	675.8	100.0	36.9	1.7	36.9	1.7	100.0	100.0						
3.03	Conc.	247.0	36.5	87.4	1.4	31.9	0.5	85.4	30.9	0.05	0.26	0.10	0.07	0.17	0.10
	Tails	430.1	63.5	8.6	1.8	5.5	1.1	14.6	69.1						
	Head	677.1	100.0	37.3	1.7	37.3	1.7	100.0	100.0						
3.04	Conc.	232.3	35.0	88.6	1.5	31.0	0.5	84.1	28.8	0.10	0.10	0.10	0.07	0.17	0.10
	Tails	431.3	65.0	9.0	2.0	5.8	1.3	15.9	71.2						
	Head	663.6	100.0	36.9	1.8	36.9	1.8	100.0	100.0						
3.05	Conc.	241.8	36.1	88.6	1.4	32.0	0.5	85.3	30.5	0.10	0.16	0.10	0.07	0.17	0.10
	Tails	428.5	63.9	8.6	1.8	5.5	1.2	14.7	69.5						
	Head	670.3	100.0	37.5	1.7	37.5	1.7	100.0	100.0						
3.06	Conc.	246.1	36.7	88.7	1.3	32.5	0.5	86.4	29.5	0.10	0.21	0.10	0.07	0.17	0.10
	Tails	425.3	63.3	8.1	1.8	5.1	1.1	13.6	70.5						
	Head	671.4	100.0	37.6	1.6	37.6	1.6	100.0	100.0						
3.07	Conc.	233.4	34.9	89.1	1.3	31.1	0.5	84.2	27.9	0.16	0.10	0.10	0.07	0.17	0.10
	Tails	434.9	65.1	9.0	1.8	5.9	1.2	15.8	72.1						
	Head	668.3	100.0	37.0	1.6	37.0	1.6	100.0	100.0						
3.08	Conc.	241.7	36.1	88.3	1.4	31.9	0.5	84.1	28.3	0.16	0.16	0.10	0.07	0.17	0.10
	Tails	428.1	63.9	9.4	2.0	6.0	1.3	15.9	71.7						
	Head	669.8	100.0	37.9	1.8	37.9	1.8	100.0	100.0						
3.09	Conc.	244.4	36.4	88.0	1.5	32.0	0.5	84.3	32.3	0.16	0.21	0.10	0.07	0.17	0.10
	Tails	427.3	63.6	9.4	1.8	6.0	1.1	15.7	67.7						
	Head	671.7	100.0	38.0	1.7	38.0	1.7	100.0	100.0						

NOTE: 1.Brine teaperature :85 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Araeen HFD & Araeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 7

SERIES A4 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
4.01	Conc.	255.0	38.2	88.3	0.8	33.8	0.3	89.8	31.0	0.05	0.05	0.10	0.08	0.17	0.10
	Tails	412.0	61.8	6.2	1.1	3.8	0.7	10.2	69.0						
	Head	667.0	100.0	37.6	1.0	37.6	1.0	100.0	100.0						
4.02	Conc.	257.2	38.4	87.9	0.9	33.8	0.3	89.3	33.8	0.05	0.10	0.10	0.08	0.17	0.10
	Tails	412.1	61.6	6.6	1.1	4.1	0.7	10.7	66.2						
	Head	669.3	100.0	37.8	1.0	37.8	1.0	100.0	100.0						
4.03	Conc.	257.4	38.4	87.3	0.8	33.5	0.3	89.0	33.3	0.05	0.16	0.10	0.08	0.17	0.10
	Tails	412.6	61.6	6.7	1.0	4.1	0.6	11.0	66.7						
	Head	670.0	100.0	37.7	0.9	37.7	0.9	100.0	100.0						
4.04	Conc.	255.9	38.1	87.9	0.8	33.5	0.3	87.8	29.1	0.05	0.21	0.10	0.08	0.17	0.10
	Tails	414.9	61.9	7.5	1.2	4.6	0.7	12.2	70.9						
	Head	670.8	100.0	38.2	1.0	38.2	1.0	100.0	100.0						
4.05	Conc.	264.4	39.2	85.8	1.1	33.6	0.4	91.5	36.1	0.10	0.05	0.10	0.08	0.17	0.10
	Tails	410.8	60.8	5.1	1.3	3.1	0.8	8.5	63.9						
	Head	675.2	100.0	36.7	1.2	36.7	1.2	100.0	100.0						
4.06	Conc.	254.4	38.3	88.2	0.9	33.8	0.3	90.1	33.7	0.10	0.10	0.10	0.08	0.17	0.10
	Tails	410.3	61.7	6.0	1.1	3.7	0.7	9.9	66.3						
	Head	664.7	100.0	37.5	1.0	37.5	1.0	100.0	100.0						
4.07	Conc.	261.2	39.0	87.1	1.1	34.0	0.4	90.9	35.1	0.10	0.16	0.10	0.08	0.17	0.10
	Tails	408.8	61.0	5.6	1.3	3.4	0.8	9.1	64.9						
	Head	670.0	100.0	37.4	1.2	37.4	1.2	100.0	100.0						

NOTE: 1.Brine temperature :81 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & Armeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

APPENDIX 3

Test Work on Series B Ores

Laboratory Procedure for Flowsheet #3

Laboratory Procedure for Flowsheet #4

TABLE 1	Fractional Analysis of Head Ore and Scrubbed Fines Fraction
TABLE 2	Fractional Analysis of Typical Series B Coarse Ores Which Had Been Scrubbed and/or Magnetically Separated
TABLE 3	Heavy Liquid Separation of Magnetic Fraction
TABLE 4	Reprocessing of Magnetic Fraction on the Permroll
TABLE 5	Series B1, Losses Incurred in Preparation of Flotation Feed
TABLE 6	Series B1, Flotation Test Results
TABLE 7	Series B2, Losses Incurred in Preparation of Flotation Feed
TABLE 8	Series B2, Flotation Test Results
TABLE 9	Series B3, Losses Incurred in Preparation of Flotation Feed
TABLE 10	Series B3, Flotation Test Results
TABLE 11	Series B4, Losses Incurred in Preparation of Flotation Feed
TABLE 12	Series B4, Flotation Test Results

Laboratory Procedure for Flowsheet #3

1. Split head ore into 800 gm lots for processing as follows.

2. Screen at 28 mesh. Oversize is about 525 gm.

3. The oversize fraction is slurried with 200 mls of brine (ie 66% solids) and scrubbed for 0.5 to 2 minutes (as required) at 900 rpm on the Denver Scrubber. The slurry is then screened at 200 mesh, using only 500 mls of brine. The -200 mesh is filtered, dried and assayed. The +200 mesh is placed in a beaker and the slurry is made up to 700 gms (ie 66% solids).

4. Scrub the undersize fraction with 450 mls of brine for 1 minute at 900 rpm on the Denver scrubber. Place slurry in 2000 ml cylinder, make up to 1000 ml level, invert 4 times, settle 2 minutes and drain to 300 ml level through drain hole on cylinder wall.

   Refill cylinder to 1000 ml level with brine, invert 4 times, filter slimes collected in both steps, dry, assay and brine correct.

   Place settled solids from cylinder in a beaker and when brine layer clears, decant to make slurry weight to 380 gms (ie 66% solids). Undersize approximately 225 gms.

5. The oversize from Step 3 is used for coarse conditioning.

   The undersize from Step 4 is used for fines conditioning.

6. Alternate to Step 3

   Where the requirement is for slurrying and desliming (no scrubbing), the electric mixer operating at 500 rpm is substituted for the Denver Scrubber. Agitation is limited to 0.5 minutes.

Laboratory Procedure for Flowsheet #4

1. Split head ore into 800 gm lots for processing as follows.

2. Screen at 28 mesh. Oversize is about 525 gms.

3. The oversize fraction is passed over the Permroll with variables at standard settings.

   The non-mag fraction is passed over the Permroll a second time. The mag fraction is weighed and assayed. Non-mags about 475 gms.

4. Scrub the undersize fraction with 450 mls of brine for 1 minute at 900 rpm on the Denver Scrubber. Place slurry in 1000 ml cylinder, make up to 1000 ml level. Invert 4 times, settle 2 minutes and drain to 300 ml level through drain hole on cylinder wall.

   Refill cylinder to 1000 ml level with brine, invert 4 times, settle for 1 minute and drain to 300 ml level.

   Filter slimes collected in both steps, dry, assay and brine correct.

   Place settled solids from cylinder in a beaker and when brine layer clears, decant to make slurry eight to 300 gms (ie 66% solids). Undersize approximately 225 gms.

5. The oversize from Step 3 is slurried with 200 mls of brine (ie 66% solids) for coarse conditioning.

   The undersize from Step 4 is used for fines conditioning.

6. Alternate to Step 5 (for test runs which required scrubbing-desliming of the non-mags)

   The oversize from Step 3 is slurried with 200 mls of brine (ie 66% solids) and scrubbed for 0.5 to 1.5 minutes (as required) at 900 rpm on the Denver Scrubber. The slurry is then screened at 200 mesh using only 500 mls of brine. The -200 mesh is filtered, dried and assayed. The +200 mesh is placed in a beaker and the slurry is made up to 700 gms (ie 66% solids) for coarse conditioning. When the requirement is for slurrying and desliming (without scrubbing), the electric mixer operating at 500 rpm is substituted for the Denver Scrubber. Agitation is limited to 0.5 minutes.

TABLE 1

FRACTIONAL ANALYSIS TYPICAL SERIES-B ORES

MESH SIZE	HEAD ORE SAMPLE WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	HEAD ORE FINES SCRUBBED AND DESLIMED ‡‡ WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
+6	0.9	23.3	10.4	0.2	0.1	0.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	10.4	30.1	7.6	3.1	0.8	8.1	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	14.4	33.8	6.0	4.9	0.9	12.6	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	13.8	39.0	4.5	5.4	0.6	13.9	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	11.2	40.3	4.0	4.5	0.4	11.7	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	11.0	42.1	3.8	4.6	0.4	12.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	8.4	44.4	3.3	3.7	0.3	9.6	5.5	18.9	48.3	1.2	9.1	0.2	21.1	4.6
48	7.7	44.6	3.4	3.4	0.3	8.9	5.2	19.9	47.6	1.6	9.5	0.3	21.9	6.4
65	5.2	44.0	3.6	2.3	0.2	5.9	3.7	13.2	46.8	1.6	6.2	0.2	14.3	4.3
100	5.3	43.1	3.9	2.3	0.2	5.9	4.1	12.7	42.5	1.9	5.4	0.2	12.5	4.9
150	2.5	42.5	4.1	1.1	0.1	2.7	2.0	4.8	42.5	2.0	2.0	0.1	4.7	1.9
200	2.6	39.2	4.6	1.0	0.1	2.6	2.4	3.7	42.4	1.9	1.6	0.1	3.6	1.4
-200	6.6	32.5	10.1	2.1	0.7	5.5	13.2	26.8	35.3	14.1	9.5	3.8	21.9	76.5
TOTAL	100.0	38.7	5.1	38.7	5.1	100.0	100.0	100.0	43.2	4.9	43.2	4.9	100.0	100.0

NOTE :‡‡ Fines -200 mesh fraction includes slime removed in desliming.

TABLE 2

FRACTIONAL ANALYSIS TYPICAL SERIES-B COARSE ORES

MESH SIZE	HEAD ORE SAMPLE WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI	HEAD ORE SLURRIED IN BRINE & DESLIMED WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI	HEAD ORE SCRUBBED 2 MINUTES AND DESLIMED WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI
+6	1.5	23.3	10.4	0.3	0.2	0.9	3.0	0.8	23.7	2.0	0.2	0.0	0.5	0.3	1.0	21.7	2.4	0.2	0.0	0.6	0.5
8	16.8	30.1	7.6	5.1	1.3	13.7	24.3	14.1	30.0	2.2	4.2	0.3	11.6	5.9	11.8	30.5	1.6	3.6	0.2	9.7	3.9
10	23.4	33.8	6.0	7.9	1.4	21.5	26.8	20.8	34.8	1.6	7.2	0.3	19.8	6.3	19.5	34.1	1.4	6.6	0.3	18.0	5.6
14	22.4	39.0	4.5	8.7	1.0	23.7	19.2	20.9	37.2	2.1	7.8	0.4	21.3	8.3	21.0	36.7	1.1	7.7	0.2	20.8	4.7
20	18.0	40.3	4.0	7.3	0.7	19.7	13.7	18.0	40.8	1.4	7.3	0.3	20.1	4.8	17.5	41.9	1.0	7.3	0.2	19.8	3.6
28	17.9	42.1	3.8	7.5	0.7	20.5	13.0	19.8	41.9	4.0	8.3	0.8	22.7	15.0	21.5	42.6	1.7	9.2	0.4	24.7	7.5
SLIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	26.7	55.9	1.5	3.1	4.1	59.4	7.7	30.7	47.0	2.4	3.6	6.4	74.2
MAGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	36.8	5.2	36.8	5.2	100.0	100.0	100.0	36.6	5.3	36.6	5.3	100.0	100.0	100.0	37.0	4.9	37.0	4.9	100.0	100.0

MESH SIZE	HEAD ORE COARSE NON MAGNETIC FRACTION WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI	HEAD ORE COARSE NON MAGNETIC FRACTION SLURRIED IN BRINE & DESLIMED WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI	HEAD ORE COARSE NON MAGNETIC FRACTION SCRUBBED 2 MINUTES AND DESLIMED WEIGHT %	ANALYSIS KCl	ANALYSIS MI	FACTOR KCl	FACTOR MI	DISTRIBUTION KCl	DISTRIBUTION MI
+6	1.0	25.8	4.8	0.3	0.0	0.7	1.0	1.0	21.2	1.2	0.2	0.0	0.6	0.3	0.7	29.2	2.9	0.2	0.0	0.6	0.4
8	13.0	30.7	2.6	4.0	0.3	10.9	7.3	11.9	27.0	1.5	3.2	0.2	8.7	3.8	12.5	29.1	1.2	3.6	0.1	9.9	3.0
10	20.0	34.3	1.2	6.9	0.2	18.7	5.2	19.2	36.3	0.8	7.0	0.2	18.9	3.3	19.7	33.3	0.8	6.6	0.2	17.8	3.1
14	20.4	38.0	0.8	7.8	0.2	21.1	3.5	19.8	38.3	0.6	7.6	0.1	20.5	2.5	19.6	38.1	0.6	7.5	0.1	20.3	2.3
20	16.8	41.0	0.7	6.9	0.1	18.7	2.5	16.8	40.3	0.4	6.8	0.1	18.3	1.4	16.3	40.8	0.4	6.7	0.1	18.1	1.3
28	18.2	43.1	0.7	7.8	0.1	21.3	2.7	19.1	42.9	0.5	8.2	0.1	22.2	2.0	18.9	43.8	0.3	8.3	0.1	22.5	1.1
MAGS	10.6	30.0	34.1	3.2	3.6	8.6	77.8	10.5	30.0	34.1	3.1	3.6	8.5	76.5	9.9	30.0	34.1	3.0	3.4	8.1	67.3
SLIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	48.8	28.0	0.8	0.5	2.2	10.2	2.4	44.0	44.6	1.1	1.1	2.9	21.3
TOTAL	100.0	36.8	4.6	36.8	4.6	100.0	100.0	100.0	36.9	4.7	36.9	4.7	100.0	100.0	100.0	36.8	5.0	36.8	5.0	100.0	100.0

TABLE 3

HEAVY LIQUID SEPARATION OF MAGNETICS FROM SERIES-B COARSE ORE

STREAM	MESH SIZE	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
FLOAT	+6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-----	8	1.0	54.2	12.9	0.5	0.1	1.9	0.3
	10	3.2	55.5	10.1	1.8	0.3	6.2	0.9
	14	6.4	58.5	5.4	3.7	0.3	13.0	0.9
	20	5.5	85.6	3.2	4.7	0.2	16.4	0.5
	-20	9.0	89.0	2.5	8.0	0.2	27.8	0.6
	TOTAL	25.1	74.8	4.8	18.8	1.2	65.3	3.2
sink	+6	0.9	20.5	69.8	0.2	0.6	0.6	1.7
----	8	12.8	17.6	60.9	2.3	7.8	7.8	20.9
	10	16.1	16.2	55.1	2.6	8.9	9.1	23.8
	14	14.9	13.1	49.5	2.0	7.4	6.8	19.8
	20	14.3	10.5	39.9	1.5	5.7	5.2	15.3
	-20	15.9	9.4	35.8	1.5	5.7	5.2	15.3
	TOTAL	74.9	13.3	48.2	10.0	36.1	34.7	96.8
HEAD	+6	0.9	20.5	69.8	0.2	0.6	0.6	1.7
----	8	13.8	20.3	57.4	2.8	7.9	9.7	21.3
	10	19.3	22.7	47.6	4.4	9.2	15.2	24.7
	14	21.3	26.7	36.2	5.7	7.7	19.8	20.7
	20	19.8	31.3	29.7	6.2	5.9	21.5	15.8
	-20	24.9	38.2	23.8	9.5	5.9	33.1	15.9
	TOTAL	100.0	28.8	37.3	28.8	37.3	100.0	100.0

NOTE :Liquid specific gravity for +14 mesh fractions =2.20.
Liquid specific gravity for -14 mesh fractions =2.15.

Reprocessing of Magnetic Fraction

Procedure:

1. Screen magnetics at 14 mesh.

2. Adjust splitter gate as required and pass +14 mesh magnetics over Permroll.

3. Adjust roll speed to 111 rpm and pass -14 mesh magnetics over Permroll. All other settings were fixed as in Appendix 1.

Results From Reprocessing Magnetics

TABLE 4

Mesh	Product	Weight %	Analysis KCl	Analysis WI	Distribution KCl	Distribution WI
6 x 14	Mags	40.6	22.0	52.5	29.3	60.3
6 x 14	Non-Mags	15.9	31.9	19.6	16.8	8.9
20 x 28	Mags	22.6	29.9	42.6	22.4	27.6
20 x 28	Non-Mags	20.9	45.7	5.4	31.5	3.2
Total		100.0	30.4	35.2	100.0	100.0

TABLE 5

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES B1

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO. 1.xx Coarse ore as is. Fines scrubbed and deslimed separately.							
FLOT FD	91.2	38.5	4.1	35.1	3.7	92.5	76.7
SLIME-F	8.8	32.3	12.9	2.8	1.1	7.5	23.3
HEAD	100.0	38.0	4.9	38.0	4.9	100.0	100.0
TEST NO. 2.XX Coarse ore slurried in brine and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	88.1	38.2	2.0	33.7	1.8	90.4	35.9
SLIME-F	8.7	32.3	12.9	2.8	1.1	7.6	22.8
SLIME-C	3.2	23.3	63.4	0.7	2.0	2.0	41.3
HEAD	100.0	37.2	4.9	37.2	4.9	100.0	100.0
TEST NO. 3.XX Coarse ore scrubbed 0.5 min. and deslimed. Fines scrubbed and deeslimed separately.							
FLOT FD	87.2	39.7	1.2	34.6	1.0	90.0	22.7
SLIME-F	8.8	32.3	12.9	2.8	1.1	7.4	24.7
SLIME-C	4.0	25.4	60.5	1.0	2.4	2.6	52.6
HEAD	100.0	38.5	4.6	38.5	4.6	100.0	100.0
TEST NO. 4.XX Coarse ore scrubbed 1.0 min. and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	86.7	39.4	1.0	34.2	0.9	89.5	18.5
SLIME-F	8.9	32.3	12.9	2.9	1.1	7.5	24.5
SLIME-C	4.4	25.4	60.5	1.1	2.7	2.9	56.9
HEAD	100.0	38.2	4.7	38.2	4.7	100.0	100.0

Note : Slime - F = Slime from fine ore.
Slime - C = Slime from coarse ore.

TABLE 6

SERIES B1 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
1.01	Conc.	66.7	9.4	63.7	17.8	6.0	1.7	15.7	41.5	0.10	0.05	0.09	0.07	0.16	0.09
	Tails	643.0	90.6	35.5	2.6	32.2	2.4	84.3	58.5						
	Head	709.7	100.0	38.2	4.0	38.2	4.0	100.0	100.0						
1.02	Conc.	106.1	14.6	78.7	11.9	11.5	1.7	29.1	41.3	0.10	0.10	0.09	0.07	0.16	0.09
	Tails	619.5	85.4	32.8	2.9	28.0	2.5	70.9	58.7						
	Head	725.6	100.0	39.5	4.2	39.5	4.2	100.0	100.0						
1.03	Conc.	120.3	16.3	79.2	9.5	12.9	1.5	33.3	38.9	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	620.0	83.7	30.8	2.9	25.8	2.4	66.7	61.1						
	Head	740.3	100.0	38.7	4.0	38.7	4.0	100.0	100.0						
1.04	Conc.	192.3	27.1	84.4	6.4	22.9	1.7	61.0	41.2	0.10	0.20	0.09	0.07	0.16	0.09
	Tails	516.9	72.9	20.1	3.4	14.6	2.5	39.0	58.8						
	Head	709.2	100.0	37.5	4.2	37.5	4.2	100.0	100.0						
2.01	Conc.	212.8	30.0	90.2	2.6	27.0	0.8	73.1	31.7	0.10	0.05	0.09	0.07	0.16	0.09
	Tails	497.1	70.0	14.2	2.4	9.9	1.7	26.9	68.3						
	Head	709.9	100.0	37.0	2.5	37.0	2.5	100.0	100.0						
2.02	Conc.	258.2	36.6	87.9	1.9	32.2	0.7	81.5	36.6	0.10	0.10	0.09	0.07	0.16	0.09
	Tails	447.0	63.4	11.5	1.9	7.3	1.2	18.5	63.4						
	Head	705.2	100.0	39.5	1.9	39.5	1.9	100.0	100.0						
2.03	Conc.	266.8	38.4	88.4	1.8	33.9	0.7	90.2	30.9	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	428.7	61.6	6.0	2.5	3.7	1.5	9.8	69.1						
	Head	695.5	100.0	37.6	2.2	37.6	2.2	100.0	100.0						
2.04	Conc.	266.7	38.0	88.7	1.4	33.7	0.5	87.0	34.9	0.10	0.20	0.09	0.07	0.16	0.09
	Tails	434.7	62.0	8.1	1.6	5.0	1.0	13.0	65.1						
	Head	701.4	100.0	38.7	1.5	38.7	1.5	100.0	100.0						
3.01	Conc.	262.4	38.2	89.5	0.6	34.2	0.2	85.9	22.2	0.10	0.05	0.09	0.07	0.16	0.09
	Tails	425.0	61.8	9.1	1.3	5.6	0.8	14.1	77.8						
	Head	687.4	100.0	39.8	1.0	39.8	1.0	100.0	100.0						
3.02	Conc.	263.2	38.2	89.7	0.6	34.3	0.2	86.4	25.2	0.10	0.10	0.09	0.07	0.16	0.09
	Tails	425.8	61.8	8.7	1.1	5.4	0.7	13.6	74.8						
	Head	689.0	100.0	39.6	0.9	39.6	0.9	100.0	100.0						
3.03	Conc.	243.0	34.6	90.2	1.3	31.2	0.4	78.7	28.8	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	460.1	65.4	12.9	1.7	8.4	1.1	21.3	71.2						
	Head	703.1	100.0	39.6	1.6	39.6	1.6	100.0	100.0						
3.04	Conc.	271.0	40.3	88.7	0.7	35.7	0.3	90.5	19.9	0.10	0.20	0.09	0.07	0.16	0.09
	Tails	401.4	59.7	6.3	1.9	3.8	1.1	9.5	80.1						
	Head	672.4	100.0	39.5	1.4	39.5	1.4	100.0	100.0						
4.01	Conc.	253.8	38.1	90.3	0.6	34.4	0.2	87.8	18.7	0.10	0.05	0.09	0.07	0.16	0.09
	Tails	412.8	61.9	7.7	1.6	4.8	1.0	12.2	81.3						
	Head	666.6	100.0	39.1	1.2	39.1	1.2	100.0	100.0						
4.02	Conc.	269.6	38.9	89.5	0.5	34.8	0.2	88.2	24.1	0.10	0.10	0.09	0.07	0.16	0.09
	Tails	423.8	61.1	7.6	1.0	4.6	0.6	11.8	75.9						
	Head	693.4	100.0	39.4	0.8	39.4	0.8	100.0	100.0						
4.03	Conc.	278.6	40.3	88.4	0.7	35.6	0.3	90.9	30.1	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	412.5	59.7	6.0	1.1	3.6	0.7	9.1	69.9						
	Head	691.1	100.0	39.2	0.9	39.2	0.9	100.0	100.0						
4.04	Conc.	277.7	41.1	87.4	0.5	36.0	0.2	90.7	21.2	0.10	0.20	0.09	0.07	0.16	0.09
	Tails	397.3	58.9	6.3	1.3	3.7	0.8	9.3	78.8						
	Head	675.0	100.0	39.7	1.0	39.7	1.0	100.0	100.0						

NOTE 1.Brine temperature :81 F
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & HT97.
4.Promoter Oil :Esso 904.
5.Frother :Shell MIBC.

TABLE 7

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES B2

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO. 5.XX Coarse ore processed on Permroll. Fines scrubbed and deslimed separately.							
FLOT FD	85.3	40.5	1.9	34.5	1.6	87.7	33.5
SLIME-F	8.5	34.9	12.9	3.0	1.1	7.5	22.7
MAGS	6.2	30.0	34.1	1.9	2.1	4.7	43.8
HEAD	100.0	39.4	4.8	39.4	4.8	100.0	100.0
TEST NO. 6.XX Coarse ore fraction processed on Permroll, slurried and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	84.0	41.0	1.1	34.4	0.9	86.6	20.6
SLIME-F	8.5	34.9	12.9	3.0	1.1	7.5	24.5
SLIME-C	1.3	37.7	26.9	0.5	0.3	1.2	7.8
MAGS	6.2	30.0	34.1	1.9	2.1	4.7	47.1
HEAD	100.0	39.8	4.5	39.8	4.5	100.0	100.0
TEST NO. 7.XX Coarse ore fraction processed on Permroll, scrubbed for 0.5 minutes and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	83.7	40.9	1.2	34.2	1.0	86.2	21.8
SLIME-F	8.6	34.9	12.9	3.0	1.1	7.6	24.0
SLIME-C	1.4	42.6	25.2	0.6	0.4	1.5	7.6
MAGS	6.3	30.0	34.1	1.9	2.1	4.8	46.6
HEAD	100.0	39.7	4.6	39.7	4.6	100.0	100.0
TEST NO. 8.XX Coarse ore fraction processed on Permroll, scrubbed for 1 minute and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	83.5	40.7	0.9	34.0	0.8	86.2	16.8
SLIME-F	8.5	34.9	12.9	3.0	1.1	7.5	24.5
SLIME-C	1.7	34.2	28.1	0.6	0.5	1.5	10.7
MAGS	6.3	30.0	34.1	1.9	2.1	4.8	48.0
HEAD	100.0	39.4	4.5	39.4	4.5	100.0	100.0

Note : Slime - F = Slime from fine ore.
Slime - C = Slime from coarse ore.

TABLE 8

SERIES B2 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
5.01	Conc.	213.9	31.0	92.1	1.6	28.6	0.5	71.5	29.7	0.11	0.06	0.10	0.08	0.17	0.10
	Tails	476.0	69.0	16.5	1.7	11.4	1.2	28.5	70.3						
	Head	689.9	100.0	39.9	1.7	39.9	1.7	100.0	100.0						
5.02	Conc.	250.0	37.2	89.7	1.7	33.3	0.6	82.1	27.9	0.11	0.11	0.10	0.08	0.17	0.10
	Tails	422.7	62.8	11.6	2.6	7.3	1.6	17.9	72.1						
	Head	672.7	100.0	40.6	2.3	40.6	2.3	100.0	100.0						
5.03	Conc.	256.0	37.8	90.1	1.3	34.1	0.5	84.1	25.6	0.11	0.16	0.10	0.08	0.17	0.10
	Tails	420.5	62.2	10.4	2.3	6.5	1.4	15.9	74.4						
	Head	676.5	100.0	40.6	1.9	40.6	1.9	100.0	100.0						
5.04	Conc.	256.7	38.0	91.0	1.2	34.6	0.5	85.3	25.9	0.11	0.21	0.10	0.08	0.17	0.10
	Tails	419.4	62.0	9.6	2.1	6.0	1.3	14.7	74.1						
	Head	676.1	100.0	40.5	1.8	40.5	1.8	100.0	100.0						
6.01	Conc.	258.6	38.8	91.3	0.7	35.4	0.3	88.5	24.1	0.11	0.06	0.10	0.08	0.17	0.10
	Tails	408.1	61.2	7.5	1.4	4.6	0.9	11.5	75.9						
	Head	666.7	100.0	40.0	1.1	40.0	1.1	100.0	100.0						
6.02	Conc.	266.3	39.7	91.0	0.7	36.2	0.3	86.8	27.8	0.11	0.11	0.10	0.08	0.17	0.10
	Tails	403.8	60.3	9.1	1.2	5.5	0.7	13.2	72.2						
	Head	670.1	100.0	41.6	1.0	41.6	1.0	100.0	100.0						
6.03	Conc.	264.3	39.6	91.2	0.7	36.1	0.3	89.0	24.7	0.11	0.16	0.10	0.08	0.17	0.10
	Tails	403.1	60.4	7.4	1.4	4.5	0.8	11.0	75.3						
	Head	667.4	100.0	40.6	1.1	40.6	1.1	100.0	100.0						
6.04	Conc.	275.4	41.4	90.1	0.7	37.3	0.3	89.6	27.5	0.11	0.21	0.10	0.08	0.17	0.10
	Tails	390.3	58.6	7.4	1.3	4.3	0.8	10.4	72.5						
	Head	665.7	100.0	41.6	1.1	41.6	1.1	100.0	100.0						
7.01	Conc.	257.1	38.7	90.9	0.6	35.2	0.2	87.5	21.3	0.11	0.06	0.10	0.08	0.17	0.10
	Tails	406.8	61.3	8.2	1.4	5.0	0.9	12.5	78.7						
	Head	663.9	100.0	40.2	1.1	40.2	1.1	100.0	100.0						
7.02	Conc.	266.4	40.4	90.6	0.9	36.6	0.4	88.1	24.3	0.11	0.11	0.10	0.08	0.17	0.10
	Tails	393.6	59.6	8.3	1.9	4.9	1.1	11.9	75.7						
	Head	660.0	100.0	41.5	1.5	41.5	1.5	100.0	100.0						
7.03	Conc.	259.0	38.9	92.0	0.5	35.8	0.2	88.3	21.0	0.11	0.16	0.10	0.08	0.17	0.10
	Tails	406.2	61.1	7.8	1.2	4.8	0.7	11.7	79.0						
	Head	665.2	100.0	40.6	0.9	40.6	0.9	100.0	100.0						
7.04	Conc.	274.1	41.7	89.4	0.6	37.3	0.3	90.4	22.2	0.11	0.21	0.10	0.08	0.17	0.10
	Tails	383.2	58.3	6.8	1.5	4.0	0.9	9.6	77.8						
	Head	657.3	100.0	41.2	1.1	41.2	1.1	100.0	100.0						
8.01	Conc.	266.8	40.4	90.5	0.6	36.6	0.2	90.3	25.3	0.11	0.06	0.10	0.08	0.17	0.10
	Tails	393.3	59.6	6.6	1.2	3.9	0.7	9.7	74.7						
	Head	660.1	100.0	40.5	1.0	40.5	1.0	100.0	100.0						
8.02	Conc.	267.1	40.3	91.4	0.5	36.9	0.2	90.2	22.0	0.11	0.11	0.10	0.08	0.17	0.10
	Tails	394.9	59.7	6.7	1.2	4.0	0.7	9.8	78.0						
	Head	662.0	100.0	40.9	0.9	40.9	0.9	100.0	100.0						
8.03	Conc.	270.2	41.1	90.3	0.5	37.1	0.2	91.3	22.6	0.11	0.16	0.10	0.08	0.17	0.10
	Tails	386.6	58.9	6.0	1.2	3.5	0.7	8.7	77.4						
	Head	656.8	100.0	40.7	0.9	40.7	0.9	100.0	100.0						
8.04	Conc.	279.9	42.2	89.6	0.6	37.8	0.3	92.2	28.5	0.11	0.21	0.10	0.08	0.17	0.10
	Tails	383.3	57.8	5.5	1.1	3.2	0.6	7.8	71.5						
	Head	663.2	100.0	41.0	0.9	41.0	0.9	100.0	100.0						

NOTE 1.Brine temperature :79 F
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & HT97.
4.Promoter Oil :Esso 904.
5.Frother :Shell MIBC.

TABLE 9

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES B3

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO. 9.XX Coarse ore fraction scrubbed for 0.5 minutes and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	87.0	39.1	1.1	34.0	1.0	89.2	20.1
SLIME-F	9.1	33.8	16.4	3.1	1.5	8.1	31.4
SLIME-C	3.9	26.4	59.0	1.0	2.3	2.7	48.4
HEAD	100.0	38.1	4.8	38.1	4.8	100.0	100.0
TEST NO.10.XX Coarse ore fraction processed on Permroll, scrubbed for 0.5 minutes and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	83.9	39.9	0.7	33.5	0.6	86.5	13.0
SLIME-F	9.1	33.8	16.4	3.1	1.5	7.9	33.1
SLIME-C	0.7	39.8	40.8	0.3	0.3	0.7	6.3
MAGS	6.3	30.0	34.1	1.9	2.1	4.9	47.6
HEAD	100.0	38.7	4.5	38.7	4.5	100.0	100.0

Note : Slime - F = Slime from fine ore.
Slime - C = Slime from coarse ore.

TABLE 10

SERIES B3 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
9.01	Conc.	233.7	33.4	90.4	0.8	30.2	0.3	78.5	25.0	0.10	0.15	0.05	0.03	0.16	0.09
	Tails	466.6	66.6	12.4	1.2	8.3	0.8	21.5	75.0						
	Head	700.3	100.0	38.4	1.1	38.4	1.1	100.0	100.0						
9.02	Conc.	254.9	38.1	90.4	0.6	34.4	0.2	88.4	22.1	0.10	0.15	0.07	0.05	0.16	0.09
	Tails	414.5	61.9	7.3	1.3	4.5	0.8	11.6	77.9						
	Head	669.4	100.0	38.9	1.0	38.9	1.0	100.0	100.0						
9.03	Conc.	267.5	38.9	89.3	0.7	34.8	0.3	90.0	24.2	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	419.5	61.1	6.3	1.4	3.8	0.9	10.0	75.8						
	Head	687.0	100.0	38.6	1.1	38.6	1.1	100.0	100.0						
9.04	Conc.	278.5	40.3	88.0	0.9	35.5	0.4	88.5	27.5	0.10	0.15	0.11	0.09	0.16	0.09
	Tails	412.1	59.7	7.7	1.6	4.6	1.0	11.5	72.5						
	Head	690.6	100.0	40.1	1.3	40.1	1.3	100.0	100.0						
10.01	Conc.	242.7	36.8	89.8	0.6	33.0	0.2	84.3	27.9	0.10	0.15	0.05	0.03	0.16	0.09
	Tails	417.5	63.2	9.7	0.9	6.1	0.6	15.7	72.1						
	Head	660.2	100.0	39.1	0.8	39.1	0.8	100.0	100.0						
10.02	Conc.	260.7	39.6	89.4	0.4	35.4	0.2	88.9	22.6	0.10	0.15	0.07	0.05	0.16	0.09
	Tails	397.2	60.4	7.3	0.9	4.4	0.5	11.1	77.4						
	Head	657.9	100.0	39.8	0.7	39.8	0.7	100.0	100.0						
10.03	Conc.	268.9	40.8	89.1	0.4	36.3	0.2	90.4	23.4	0.10	0.15	0.09	0.07	0.16	0.09
	Tails	390.5	59.2	6.5	0.9	3.8	0.5	9.6	76.6						
	Head	659.4	100.0	40.2	0.7	40.2	0.7	100.0	100.0						
10.04	Conc.	283.7	42.0	88.5	0.6	37.2	0.3	93.4	35.2	0.10	0.15	0.14	0.10	0.16	0.09
	Tails	391.3	58.0	4.5	0.8	2.6	0.5	6.6	64.8						
	Head	675.0	100.0	39.8	0.7	39.8	0.7	100.0	100.0						

NOTE: 1.Brine temperature :82 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen Hfd & Armeen HT97.
4.Promoter Oil :Esso 904.
5.Frother :Shell MIBC.

TABLE 11

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES B4

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO.11.XX Coarse ore fraction scrubbed for 0.5 min. and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	87.4	39.5	1.0	34.5	0.9	90.3	18.4
SLIME-F	8.6	31.4	17.3	2.7	1.5	7.1	31.4
SLIME-C	4.0	24.9	59.4	1.0	2.4	2.6	50.1
HEAD	100.0	38.2	4.7	38.2	4.7	100.0	100.0
TEST NO.12.XX Coarse ore fraction scrubbed for 1.0 min. and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	87.1	39.3	0.9	34.2	0.8	89.9	16.2
SLIME-F	8.5	31.4	17.3	2.7	1.5	7.0	30.3
SLIME-C	4.4	26.9	59.0	1.2	2.6	3.1	53.5
HEAD	100.0	38.1	4.9	38.1	4.9	100.0	100.0
TEST NO.13.XX Coarse ore fraction processed on Permroll, slurried and deslimed. Fines scrubbed and deslimed separately.							
FLOT FD	84.0	39.9	0.9	33.5	0.8	87.1	15.7
SLIME-F	8.5	31.4	17.3	2.7	1.5	6.9	30.5
SLIME-C	1.3	33.2	36.9	0.4	0.5	1.1	10.0
MAGS	6.2	30.0	34.1	1.9	2.1	4.8	43.9
HEAD	100.0	38.5	4.8	38.5	4.8	100.0	100.0

Note : Slime - F = Slime from fine ore.
Slime - C = Slime from coarse ore.

TABLE 12

SERIES B4 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
11.01	Conc.	267.0	38.8	87.9	0.9	34.1	0.3	86.6	32.2	0.10	0.15	0.05	0.04	0.15	0.09
	Tails	422.0	61.2	8.6	1.2	5.3	0.7	13.4	67.8						
	Head	689.0	100.0	39.3	1.1	39.3	1.1	100.0	100.0						
11.02	Conc.	272.5	39.4	88.0	0.7	34.6	0.3	89.1	29.2	0.10	0.15	0.08	0.06	0.15	0.09
	Tails	419.6	60.6	7.0	1.1	4.2	0.7	10.9	70.8						
	Head	692.1	100.0	38.9	0.9	38.9	0.9	100.0	100.0						
11.03	Conc.	293.6	42.1	86.9	0.8	36.6	0.3	91.7	30.9	0.10	0.15	0.11	0.08	0.15	0.09
	Tails	403.3	57.9	5.7	1.3	3.3	0.8	8.3	69.1						
	Head	696.9	100.0	39.9	1.1	39.9	1.1	100.0	100.0						
11.04	Conc.	287.3	41.9	87.7	0.7	36.8	0.3	92.1	29.6	0.10	0.15	0.14	0.11	0.15	0.09
	Tails	397.8	58.1	5.4	1.2	3.1	0.7	7.9	70.4						
	Head	685.1	100.0	39.9	1.0	39.9	1.0	100.0	100.0						
12.01	Conc.	257.4	37.5	90.5	0.5	33.9	0.2	88.4	25.0	0.10	0.15	0.05	0.04	0.15	0.09
	Tails	429.1	62.5	7.1	0.9	4.4	0.6	11.6	75.0						
	Head	686.5	100.0	38.4	0.8	38.4	0.8	100.0	100.0						
12.02	Conc.	272.0	39.5	89.7	0.8	35.4	0.3	89.1	39.5	0.10	0.15	0.08	0.06	0.15	0.09
	Tails	416.5	60.5	7.2	0.8	4.4	0.5	10.9	60.5						
	Head	688.5	100.0	39.8	0.8	39.8	0.8	100.0	100.0						
12.03	Conc.	281.1	40.7	87.8	0.7	35.7	0.3	90.8	32.5	0.10	0.15	0.11	0.08	0.15	0.09
	Tails	409.6	59.3	6.1	1.0	3.6	0.6	9.2	67.5						
	Head	690.7	100.0	39.4	0.9	39.4	0.9	100.0	100.0						
12.04	Conc.	292.4	41.8	88.0	0.8	36.8	0.3	92.3	32.4	0.10	0.15	0.14	0.11	0.15	0.09
	Tails	406.8	58.2	5.3	1.2	3.1	0.7	7.7	67.6						
	Head	699.2	100.0	39.9	1.0	39.9	1.0	100.0	100.0						
13.01	Conc.	233.7	34.6	91.2	0.4	31.5	0.1	79.5	20.9	0.10	0.15	0.05	0.04	0.15	0.09
	Tails	442.1	65.4	12.4	0.8	8.1	0.5	20.5	79.1						
	Head	675.8	100.0	39.7	0.7	39.7	0.7	100.0	100.0						
13.02	Conc.	260.4	39.2	90.1	0.6	35.3	0.2	90.1	32.6	0.10	0.15	0.08	0.06	0.15	0.09
	Tails	404.1	60.8	6.4	0.8	3.9	0.5	9.9	67.4						
	Head	664.5	100.0	39.2	0.7	39.2	0.7	100.0	100.0						
13.03	Conc.	277.9	42.0	88.9	0.5	37.3	0.2	91.5	26.6	0.10	0.15	0.11	0.08	0.15	0.09
	Tails	384.0	58.0	6.0	1.0	3.5	0.6	8.5	73.4						
	Head	661.9	100.0	40.8	0.8	40.8	0.8	100.0	100.0						
13.04	Conc.	286.8	42.4	87.7	0.7	37.2	0.3	92.7	23.3	0.10	0.15	0.14	0.11	0.15	0.09
	Tails	389.5	57.6	5.1	1.7	2.9	1.0	7.3	76.7						
	Head	676.3	100.0	40.1	1.3	40.1	1.3	100.0	100.0						

NOTE: 1.Brine temperature :82 F
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & HT97.
4.Promoter Oil :Esso 904.
5.Frother :Shell MIBC.

APPENDIX 4

Test Work on Series C Ores

Laboratory Procedure for Flowsheet #5

Laboratory Procedure for Flowsheet #6

Table 1	Fractional Analysis of Typical Series C Ores
Table 2	Fractional Analysis of Magnetic Fractions
Table 3	Series C1, Losses Incurred in Preparation of Flotation Feed
Table 4	Series C1, Flotation Test Results
Table 5	Series C2, Losses Incurred in Preparation of Flotation Feed
Table 6	Series C2, Flotation Test Results
Table 7	Series C3, Losses Incurred in Preparation of Flotation Feed
Table 8	Series C3, Flotation Test Results
Table 9	Series C4, Losses Incurred in Preparation of Flotation Feed
Table 10	Series C4, Flotation Test Results

LABORATORY PROCEDURE FOR FLOWSHEET #5

1. Split head ore into 800 gm lots for processing as follows.

2. Scrub for 3 minutes at 900 rpm on Denver Scrubber with 300 mls of brine at 68% solids.

3. Wet screen sample at 28 mesh using only 500 mls of brine.

4. Place +28 mesh in beaker and when solids settle, decant clear brine so that slurry weight is 750 gms (ie 66% solids).

5. The -28 mesh is wet screened at 200 mesh until clean. The +200 mesh is placed in a beaker and when solids settle, decant clear brine so that slurry weight is 300 gms (ie 60% solids).

6. The -200 mesh is filtered, dried and assayed.

7. The +28 mesh from Step 4 and the +200 mesh from Step 5 are used for conditioning as coarse and fines respectively for flotation tests.

NOTE: In Step 2, the scrubbing time may be varied as required for the particular run of tests.

LABORATORY PROCEDURE FOR FLOWSHEET #6

1. Split head ore into 800 gm lots for processing as follows.
2. Screen at 28 mesh. About 60% weight will be oversize.
3. The oversize fraction is passed over the Permroll with standard settings.
4. The magnetic fraction is screened at 14 mesh and the -14 mesh is passed over the Permroll again with belt speed set at 111 rpm.
5. The non-magnetics from Steps 3 and 4 are combined with the -28 mesh ore from Step 2.
6. Scrubbing and desliming is performed as described under Laboratory Procedure for Flowsheet #5.

TABLE 1

FRACTIONAL ANALYSIS TYPICAL SERIES-C ORES

MESH SIZE	HEAD ORE SAMPLE WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	HEAD ORE SCRUBBED 3 MINUTES AND DESLIMED[‡‡] WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
+6	1.7	20.1	7.0	0.3	0.1	0.9	3.0	1.2	32.8	1.3	0.4	0.0	1.0	0.4
8	12.4	30.1	4.9	3.7	0.6	9.3	15.4	9.7	34.3	1.8	3.3	0.2	8.1	3.9
10	14.6	36.8	4.0	5.4	0.6	13.4	14.8	13.0	37.7	1.4	4.9	0.2	12.0	4.1
14	13.5	39.8	3.7	5.4	0.5	13.4	12.6	12.6	39.8	1.5	5.0	0.2	12.2	4.3
20	10.6	42.4	3.4	4.5	0.4	11.2	9.1	10.3	41.8	1.2	4.3	0.1	10.5	2.8
28	10.8	45.1	3.3	4.9	0.4	12.1	9.0	10.6	42.4	0.9	4.5	0.1	11.0	2.2
35	7.5	47.2	3.2	3.5	0.2	8.8	6.1	7.6	44.8	0.6	3.4	0.0	8.3	1.0
48	7.1	47.2	3.3	3.4	0.2	8.4	5.9	7.3	45.2	0.6	3.3	0.0	8.1	1.0
65	4.7	46.1	3.4	2.2	0.2	5.4	4.0	4.6	45.3	0.5	2.1	0.0	5.1	0.5
100	5.2	46.3	3.5	2.4	0.2	6.0	4.6	5.0	45.4	0.4	2.3	0.0	5.5	0.5
150	2.4	44.1	3.6	1.1	0.1	2.6	2.2	2.4	44.7	0.4	1.1	0.0	2.6	0.2
200	2.5	41.7	3.9	1.0	0.1	2.6	2.5	2.3	41.2	0.4	0.9	0.0	2.3	0.2
-200	7.0	33.8	6.1	2.4	0.4	5.9	10.8	13.4	40.6	26.1	5.4	3.5	13.3	79.0
TOTAL	100.0	40.1	4.0	40.1	4.0	100.0	100.0	100.0	41.0	4.4	41.0	4.4	100.0	100.0

NOTE :‡‡ The -200 mesh fraction includes slime removed in desliming.

TABLE 2

FRACTIONAL ANALYSIS OF MAGNETIC FRACTIONS - SERIES C ORES

PRODUCT	WEIGHT		ANALYSIS		FACTOR		DISTRIBUTION	
	GRAMS	%	KCl	WI	KCl	WI	KCl	WI
Analysis of various fractions that made up the original magnetics.								
+14M MAGS	29.0	58.0	26.9	44.0	15.6	25.5	46.9	75.4
-14M MAGS	11.0	22.0	32.8	34.3	7.2	7.5	21.7	22.3
-14M NON MAGS	10.0	20.0	52.3	3.8	10.5	0.8	31.4	2.2
TOTAL MAGS	50.0	100.0	33.3	33.8	33.3	33.8	100.0	100.0
Analysis of final magnetic reject.								
+14M MAGS	29.0	72.5	26.9	44.0	19.5	31.9	68.4	77.2
-14M MAGS	11.0	27.5	32.8	34.3	9.0	9.4	31.6	22.8
TOTAL REJECT	40.0	100.0	28.5	41.3	28.5	41.3	100.0	100.0
Analysis of various fractions that make up the original ore.								
6x28 NON MAGS	475.0	59.4	37.8	1.0	22.4	0.6	56.9	15.1
FINE ORE	275.0	34.4	43.4	3.6	14.9	1.2	37.8	31.4
-14M NON MAGS	10.0	1.2	52.3	3.8	0.7	0.0	1.7	1.2
MAG REJECT	40.0	5.0	28.5	41.3	1.4	2.1	3.6	52.4
HEAD	800.0	100.0	39.4	3.9	39.4	3.9	100.0	100.0

TABLE 3

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES C1

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
All tests : Scrubbing time for ore - 3 minutes.							
FLOT FD	87.8	41.0	0.7	36.0	0.6	87.9	15.0
SLIME	12.2	40.7	28.5	5.0	3.5	12.1	85.0
HEAD	100.0	41.0	4.1	41.0	4.1	100.0	100.0

TABLE 4

SERIES C1 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	Percent	ANALYSIS KCl	MI	FACTOR KCl	MI	DISTRIBUTION KCl	MI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	COARSE	ARMEEN HFD	HT97	ESSO 904	SHELL MIBC
1.01	Conc.	268.6	39.2	91.1	0.4	35.7	0.2	87.6	22.3	0.01	0.09	0.10	0.09	0.06	0.09
	Tails	416.8	60.8	8.3	0.9	3.0	0.5	12.4	77.7						
	Head	685.4	100.0	40.7	0.7	40.7	0.7	100.0	100.0						
1.02	Conc.	282.8	41.0	89.6	0.4	36.8	0.2	89.9	23.6	0.02	0.18	0.10	0.09	0.16	0.09
	Tails	406.2	59.0	7.0	0.9	4.1	0.5	10.1	76.4						
	Head	689.0	100.0	40.9	0.7	40.9	0.7	100.0	100.0						
1.03	Conc.	278.4	40.4	91.7	0.3	37.0	0.1	90.4	20.2	0.03	0.27	0.10	0.09	0.16	0.09
	Tails	411.5	59.6	6.6	0.8	3.9	0.5	9.6	79.8						
	Head	689.9	100.0	40.9	0.6	40.9	0.6	100.0	100.0						
1.04	Conc.	284.6	41.5	90.5	0.3	37.6	0.1	92.4	19.1	0.04	0.36	0.10	0.09	0.16	0.09
	Tails	401.1	58.5	5.3	0.9	3.1	0.5	7.6	80.9						
	Head	685.7	100.0	40.7	0.7	40.7	0.7	100.0	100.0						
1.05	Conc.	270.8	38.9	91.4	0.5	35.6	0.2	86.9	24.2	0.02	0.08	0.10	0.09	0.16	0.09
	Tails	424.7	61.1	8.8	1.0	5.4	0.6	13.1	75.8						
	Head	695.5	100.0	41.0	0.8	41.0	0.8	100.0	100.0						
1.06	Conc.	299.4	43.0	90.0	0.3	38.7	0.1	92.3	22.1	0.05	0.15	0.10	0.09	0.16	0.09
	Tails	396.5	57.0	5.7	0.8	3.2	0.5	7.7	77.9						
	Head	695.9	100.0	42.0	0.6	42.0	0.6	100.0	100.0						
1.07	Conc.	286.2	41.7	91.4	0.3	38.1	0.1	91.3	21.1	0.08	0.22	0.10	0.09	0.16	0.09
	Tails	400.5	58.3	6.2	0.8	3.6	0.5	8.7	78.9						
	Head	686.7	100.0	41.7	0.6	41.7	0.6	100.0	100.0						
1.08	Conc.	285.0	40.9	90.8	0.4	37.1	0.2	90.8	25.7	0.10	0.30	0.10	0.09	0.16	0.09
	Tails	411.7	59.1	6.4	0.8	3.8	0.5	9.2	74.3						
	Head	696.7	100.0	40.9	0.6	40.9	0.6	100.0	100.0						
1.09	Conc.	283.2	40.9	90.1	0.4	36.9	0.2	90.7	21.7	0.04	0.06	0.10	0.09	0.16	0.09
	Tails	409.2	59.1	6.4	1.0	3.8	0.6	9.3	78.3						
	Head	692.4	100.0	40.6	0.8	40.6	0.8	100.0	100.0						
1.10	Conc.	280.2	40.3	91.1	0.4	36.8	0.2	89.4	25.3	0.08	0.12	0.10	0.09	0.16	0.09
	Tails	414.3	59.7	7.3	0.8	4.4	0.5	10.6	74.7						
	Head	694.5	100.0	41.1	0.6	41.1	0.6	100.0	100.0						
1.11	Conc.	283.5	40.9	90.7	0.4	37.1	0.2	90.4	28.4	0.12	0.18	0.10	0.09	0.16	0.09
	Tails	409.2	59.1	6.7	0.7	4.0	0.4	9.6	71.6						
	Head	692.7	100.0	41.1	0.6	41.1	0.6	100.0	100.0						
1.12	Conc.	287.0	41.4	89.9	0.5	37.2	0.2	90.7	28.2	0.16	0.24	0.10	0.09	0.16	0.09
	Tails	406.8	58.6	6.5	0.9	3.8	0.5	9.3	71.8						
	Head	693.8	100.0	41.0	0.7	41.0	0.7	100.0	100.0						

NOTE: 1.Brine temperature :80 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Araeen HFD & Araeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 5

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES C2

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO. 2.xx	Ore scrubbed for 1.0 minute and deslimed.						
FLOT FD	88.3	40.3	0.8	35.6	0.7	88.8	16.8
SLIME-F	11.7	38.4	30.0	4.5	3.5	11.2	83.2
HEAD	100.0	40.1	4.2	40.1	4.2	100.0	100.0
TEST NO. 3.xx	Ore scrubbed for 2.0 minute and deslimed.						
FLOT FD	86.9	40.9	0.5	35.5	0.4	87.2	10.4
SLIME-F	13.1	40.0	28.6	5.2	3.7	12.8	89.6
HEAD	100.0	40.8	4.2	40.8	4.2	100.0	100.0
TEST NO. 4.xx	Ore scrubbed for 3.0 minute and deslimed.						
FLOT FD	86.3	40.9	0.6	35.3	0.5	86.2	12.4
SLIME-F	13.7	41.1	26.6	5.6	3.6	13.8	87.6
HEAD	100.0	40.9	4.2	40.9	4.2	100.0	100.0

TABLE 6

SERIES C2 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT Grams	WEIGHT Percent	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI	REAGENT DOSAGE LB/TON FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
2.01	Conc.	181.7	25.7	90.3	1.4	23.2	0.4	60.4	30.5	0.01	0.04	0.10	0.07	0.06	0.09
	Tails	526.4	74.3	20.4	1.1	15.2	0.8	39.6	69.5						
	Head	708.1	100.0	38.3	1.2	38.3	1.2	100.0	100.0						
2.02	Conc.	262.5	37.2	90.5	0.9	33.6	0.3	82.1	32.6	0.02	0.08	0.10	0.07	0.16	0.09
	Tails	443.7	62.8	11.7	1.1	7.4	0.7	17.9	67.4						
	Head	706.2	100.0	41.0	1.0	41.0	1.0	100.0	100.0						
2.03	Conc.	283.9	40.2	90.6	0.4	36.4	0.2	89.3	25.1	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	423.1	59.8	7.3	0.8	4.4	0.5	10.7	74.9						
	Head	707.0	100.0	40.7	0.6	40.7	0.6	100.0	100.0						
2.04	Conc.	289.5	41.3	89.5	0.3	37.0	0.1	90.4	23.2	0.08	0.22	0.10	0.07	0.16	0.09
	Tails	411.6	58.7	6.7	0.7	3.9	0.4	9.6	76.8						
	Head	701.1	100.0	40.9	0.5	40.9	0.5	100.0	100.0						
3.01	Conc.	275.4	39.4	90.5	0.3	35.7	0.1	88.4	28.1	0.01	0.04	0.10	0.07	0.16	0.09
	Tails	423.7	60.6	7.7	0.5	4.7	0.3	11.6	71.9						
	Head	699.1	100.0	40.3	0.4	40.3	0.4	100.0	100.0						
3.02	Conc.	289.5	41.5	89.5	0.4	37.2	0.2	89.8	24.0	0.02	0.08	0.10	0.07	0.16	0.09
	Tails	407.4	58.5	7.2	0.9	4.2	0.5	10.2	76.0						
	Head	696.9	100.0	41.4	0.7	41.4	0.7	100.0	100.0						
3.03	Conc.	288.7	41.2	89.4	0.3	36.8	0.1	91.1	26.0	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	411.8	58.8	6.1	0.6	3.6	0.4	8.9	74.0						
	Head	700.5	100.0	40.4	0.5	40.4	0.5	100.0	100.0						
3.04	Conc.	293.3	41.9	90.0	0.3	37.7	0.1	91.2	26.5	0.08	0.22	0.10	0.07	0.16	0.09
	Tails	406.4	58.1	6.3	0.6	3.7	0.3	8.8	73.5						
	Head	699.7	100.0	41.4	0.5	41.4	0.5	100.0	100.0						
4.01	Conc.	268.6	38.4	91.1	0.3	34.9	0.1	86.6	18.9	0.01	0.04	0.10	0.07	0.16	0.09
	Tails	431.7	61.6	8.8	0.8	5.4	0.5	13.4	81.1						
	Head	700.3	100.0	40.4	0.6	40.4	0.6	100.0	100.0						
4.02	Conc.	294.7	42.3	89.0	0.3	37.7	0.1	90.3	26.9	0.02	0.08	0.10	0.07	0.16	0.09
	Tails	401.4	57.7	7.0	0.6	4.0	0.3	9.7	73.1						
	Head	696.1	100.0	41.7	0.5	41.7	0.5	100.0	100.0						
4.03	Conc.	277.6	39.9	89.5	0.3	35.7	0.1	89.6	24.9	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	417.9	60.1	6.9	0.6	4.1	0.4	10.4	75.1						
	Head	695.5	100.0	39.9	0.5	39.9	0.5	100.0	100.0						
4.04	Conc.	296.5	42.9	88.3	0.3	37.9	0.1	91.4	20.0	0.08	0.22	0.10	0.07	0.16	0.09
	Tails	395.2	57.1	6.2	0.9	3.5	0.5	8.6	80.0						
	Head	691.7	100.0	41.4	0.6	41.4	0.6	100.0	100.0						

NOTE: 1.Brine temperature :80 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & Armeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 7

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES C3

PRODUCT	WEIGHT %	ANALYSIS KCl	ANALYSIS WI	FACTOR KCl	FACTOR WI	DISTRIBUTION KCl	DISTRIBUTION WI
TEST NO. 5.XX Coarse ore processed on Permroll then combined with the fines - scrubbed for 0.5 minutes and deslimed.							
FLOT FD	85.2	41.5	0.4	35.4	0.3	86.5	7.9
SLIME	9.8	41.6	19.6	4.1	1.9	10.0	44.4
MAGS	5.0	28.5	41.3	1.4	2.1	3.5	47.7
HEAD	100.0	40.9	4.3	40.9	4.3	100.0	100.0
TEST NO. 6.XX Coarse ore processed on Permroll then combined with the fines - scrubbed for 1.0 minutes and deslimed.							
FLOT FD	84.7	40.8	0.4	34.6	0.3	85.8	7.5
SLIME	10.3	41.5	20.3	4.3	2.1	10.6	46.5
MAGS	5.0	28.5	41.3	1.4	2.1	3.5	45.9
HEAD	100.0	40.3	4.5	40.3	4.5	100.0	100.0

TABLE 8

SERIES C3 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT		ANALYSIS		FACTOR		DISTRIBUTION		REAGENT DOSAGE LB/TON					
		Grams	Percent	KCl	WI	KCl	WI	KCl	WI	FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
5.01	Conc.	252.9	36.9	89.4	0.4	33.0	0.1	80.6	28.1	0.01	0.04	0.10	0.07	0.06	0.09
	Tails	432.4	63.1	12.6	0.6	8.0	0.4	19.4	71.9						
	Head	685.3	100.0	40.9	0.5	40.9	0.5	100.0	100.0						
5.02	Conc.	284.0	41.3	88.3	0.2	36.4	0.1	88.6	21.9	0.02	0.08	0.10	0.07	0.16	0.09
	Tails	404.4	58.7	8.0	0.5	4.7	0.3	11.4	78.1						
	Head	688.4	100.0	41.1	0.4	41.1	0.4	100.0	100.0						
5.03	Conc.	282.6	41.4	88.4	0.2	36.6	0.1	88.1	19.1	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	399.8	58.6	8.4	0.6	4.9	0.4	11.9	80.9						
	Head	682.4	100.0	41.5	0.4	41.5	0.4	100.0	100.0						
5.04	Conc.	276.9	40.8	89.1	0.2	36.3	0.1	85.6	18.7	0.08	0.22	0.10	0.07	0.16	0.09
	Tails	402.5	59.2	10.3	0.6	6.1	0.4	14.4	81.3						
	Head	679.4	100.0	42.4	0.4	42.4	0.4	100.0	100.0						
6.01	Conc.	268.9	40.3	90.0	0.2	36.2	0.1	86.5	21.2	0.01	0.04	0.10	0.07	0.16	0.09
	Tails	398.8	59.7	9.5	0.5	5.7	0.3	13.5	78.8						
	Head	667.7	100.0	41.9	0.4	41.9	0.4	100.0	100.0						
6.02	Conc.	267.2	39.3	90.7	0.2	35.7	0.1	88.5	17.8	0.02	0.08	0.10	0.07	0.16	0.09
	Tails	412.6	60.7	7.6	0.6	4.6	0.4	11.5	82.2						
	Head	679.8	100.0	40.3	0.4	40.3	0.4	100.0	100.0						
6.03	Conc.	277.4	41.3	88.6	0.2	36.6	0.1	90.0	19.0	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	394.9	58.7	6.9	0.6	4.1	0.4	10.0	81.0						
	Head	672.3	100.0	40.6	0.4	40.6	0.4	100.0	100.0						
6.04	Conc.	278.9	41.1	88.6	0.3	36.4	0.1	90.0	23.0	0.08	0.22	0.10	0.07	0.16	0.09
	Tails	399.6	58.9	6.9	0.7	4.1	0.4	10.0	77.0						
	Head	678.5	100.0	40.5	0.5	40.5	0.5	100.0	100.0						

NOTE: 1.Brine temperature :80 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen HFD & Armeen HT97.
4.Promoter Oil :Esso 904
5.Frother :SHELL MIBC

TABLE 9

LOSSES INCURRED IN PREPARATION OF FLOTATION FEED
SERIES C4

PRODUCT	WEIGHT	ANALYSIS		FACTOR		DISTRIBUTION	
	%	KCl	WI	KCl	WI	KCl	WI
TEST NO. 7.XX Ore scrubbed for 2 minutes and deslimed.							
FLOT FD	86.7	40.8	0.6	35.4	0.5	86.7	13.7
SLIME	13.3	40.9	24.6	5.4	3.3	13.3	86.3
HEAD	100.0	40.8	3.8	40.8	3.8	100.0	100.0
TEST NO. 8.XX Coarse ore fraction processed on Permroll, combined with fines, scrubbed for 1 minute and deslimed.							
FLOT FD	85.3	41.3	0.4	35.2	0.3	86.8	8.0
SLIME	9.7	40.7	19.1	3.9	1.9	9.7	43.5
MAGS	5.0	28.5	41.3	1.4	2.1	3.5	48.5
HEAD	100.0	40.6	4.3	40.6	4.3	100.0	100.0

TABLE 10

SERIES C4 - FLOTATION TEST RESULTS

TEST NO.	PROD.	WEIGHT		ANALYSIS		FACTOR		DISTRIBUTION		REAGENT DOSAGE LB/TON					
		Grams	Percent	KCl	WI	KCl	WI	KCl	WI	FINNFIX 300 FINES	FINNFIX 300 COARSE	ARMEEN HFD	ARMEEN HT97	ESSO 904	SHELL MIBC
7.01	Conc.	237.8	34.3	90.6	0.4	31.1	0.1	76.5	25.9	0.05	0.15	0.05	0.04	0.16	0.09
	Tails	454.5	65.7	14.6	0.6	9.6	0.4	23.5	74.1						
	Head	692.3	100.0	40.7	0.5	40.7	0.5	100.0	100.0						
7.02	Conc.	264.5	38.1	89.9	0.3	34.3	0.1	83.9	20.9	0.05	0.15	0.07	0.05	0.16	0.09
	Tails	428.9	61.9	10.6	0.7	6.6	0.4	16.1	79.1						
	Head	693.4	100.0	40.8	0.5	40.8	0.5	100.0	100.0						
7.03	Conc.	261.7	37.4	90.7	0.4	33.9	0.1	83.8	25.5	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	437.5	62.6	10.5	0.7	6.6	0.4	16.2	74.5						
	Head	699.2	100.0	40.5	0.6	40.5	0.6	100.0	100.0						
7.04	Conc.	285.4	41.0	89.2	0.4	36.6	0.2	88.7	28.4	0.05	0.15	0.12	0.09	0.16	0.09
	Tails	410.3	59.0	7.9	0.7	4.7	0.4	11.3	71.6						
	Head	695.7	100.0	41.3	0.6	41.3	0.6	100.0	100.0						
8.01	Conc.	220.8	32.0	90.1	0.2	28.8	0.1	70.1	15.9	0.05	0.15	0.05	0.04	0.16	0.09
	Tails	468.8	68.0	18.1	0.5	12.3	0.3	29.9	84.1						
	Head	689.6	100.0	41.2	0.4	41.2	0.4	100.0	100.0						
8.02	Conc.	256.7	37.5	89.2	0.1	33.4	0.0	81.6	10.7	0.05	0.15	0.07	0.05	0.16	0.09
	Tails	428.1	62.5	12.1	0.5	7.6	0.3	18.4	89.3						
	Head	684.8	100.0	41.0	0.4	41.0	0.4	100.0	100.0						
8.03	Conc.	265.3	38.5	89.3	0.2	34.4	0.1	83.3	17.3	0.05	0.15	0.10	0.07	0.16	0.09
	Tails	423.2	61.5	11.2	0.6	6.9	0.4	16.7	82.7						
	Head	688.5	100.0	41.3	0.4	41.3	0.4	100.0	100.0						
8.04	Conc.	279.5	40.8	88.3	0.1	36.1	0.0	86.4	12.1	0.05	0.15	0.12	0.09	0.16	0.09
	Tails	404.8	59.2	9.6	0.5	5.7	0.3	13.6	87.9						
	Head	684.3	100.0	41.7	0.3	41.7	0.3	100.0	100.0						

NOTE: 1.Brine temperature :78 F.
2.Depressant CMC :Finnfix 300.
3.Collector Amine :Armeen Hfd & Armeen HT97.
4.Promoter Oil :Esso 904.
5.Frother :Shell MIBC.

APPENDIX 5

Laboratory Procedure for Reagent Preparation, Conditioning and Flotation

A. Reagent Preparation

1. Depressant (Finnfix 300)

a. Weigh out 1.4 gms of Finnfix 300.
b. Weigh out 98.6 gms of water in a 200 ml beaker.
c. Stir the water on a magnetic stirrer and slowly add the Finnfix to the vortex over a 15 minute period.
d. Stir until fully dispersed and store overnight.

2. Long Chain Collector (Armeen HFD)

a. Weigh out 1.85 gms of Armeen HFD.
b. Weight out 97.4 gms of hot (185° F) water in a 200 ml beaker.
c. Measure out 0.6 mls of 20° Baume muriatic acid.
d. Stir the hot water on the magnetic stirrer-hot plate and add the HFD and acid to the water.
e. Stir until the reaction is complete and store at 170° F.

The resulting HFD mix will have a solution strength of 2.0 - 2.1% weight amine due to evaporation.

3. Short Chain Collector (Armeen HT97)

a. Weigh out 1.86 gms of Armeen HT97.
b. Weigh out 97.4 gms of hot (150° F) water in a 200 ml beaker.
c. Measure out 0.7 mls of 20° Baume muriatic acid.
d. Stir the water on the magnetic stirrer-hot plate and add the HT97 and acid to the water.
e. Stir until the reaction is complete and store at 170° F.

The resulting HT97 mix will have a solution strength of 2.0 - 2.1% weight amine due to evaporation.

4. Promoter (ESSO 904 Oil)

The oil is placed in a water bath and heated to 170° F.

B. Conditioning

The deslimed ore is conditioned as follows:

1. Adjust electric stirrer blade height to 0.5" above table level, stirrer speed is adjusted to 460 rpm.

2. Deslimed fines are placed in a 1000 ml beaker and stirred for 10 seconds. The fines depressant is then added to the beaker and stirred for a further 30 seconds.

3. The deslimed coarse is placed in the 1000 ml conditioner and stirred for 15 seconds. The coarse depressant is then added and stirred for a further 30 seconds.

4. The HFD and HI97 are then added to the coarse and stirred for 30 seconds.

5. The oil is then added to the coarse and stirred for 30 seconds.

6. The fines are added to the coarse and stirred for 30 seconds.

7. The MIBC is then added and stirred for 30 seconds.

8. The conditioned pulp is then placed in the 1000 gm flotation cell.

C. Flotation

The WEMCO flotation machine is used for all tests with the 1000 gm cell complete with baffles.

1. Add brine to the flotation cell until the baffles are covered.

2. The flotation cell agitator is operated for 10 seconds and the air valve is then opened.

3. The potash froth is skimmed off the cell for a period of 1 minute during which 2 litres of brine is added to maintain cell level.

4. After 1 minute the agitator is shut off and the tailing remaining in the cell and the concentrate that was skimmed off is filtered and dried for assay of KCl and WI. The assays are brine corrected.

APPENDIX 6

Literature Search on Halite Activation

NORANDA RESEARCH CENTRE

Information Memorandum

9 March 1988

TO	A. Pereira, CCP
FROM	J.Y. Kim
SUBJECT	Research Assistance - CCP (N-8821-12) - Literature Survey of Non-Conventional Magnetic Separation
Copies	E.J. Brokx, SMCPR Members, KGS, GRK/PT/File

SUMMARY

A comprehensive literature survey of non-conventional magnetic separation processes was carried out to supplement the on-going research project at CCP and to evaluate the applicability of the processes in the potash industry.

The non-conventional processes identified are as follows:

(a) Magnetic coating method : this method utilizes the surface property of particles to coat magnetic materials preferentially on a particular phase prior to magnetic separation. This method includes the use of iron pentacarbonyl or surfactant treated magnetic particulates (magnetic carrier separation) for coating the particles.

(b) Sink-float method : this method includes (i) magnetogravimetric separation using colloidal magnetic suspensions, (ii) magnetohydrostatic separation using paramagnetic solutions, and (iii) magnetohydrodynamic separation using crossed magnetic and electric fields.

Although some promising results have been obtained during the development work, none of the above techniques have yet been commercially proven. Most of the processes utilize relatively expensive reagents (colloidal magnetite or $MnCl_2$) or toxic chemicals, except the carrier separation process. A small scale magnetohydrodynamic separator was tested for separating carnotite from salts in a specially prepared magnetic fluid. No follow-ups are available.

Of the processes evaluated, only the carrier magnetic separation process seems to have some potential in the potash operation, since ionic collectors such as amines or oleic acid can be used as carrier medium, for preferential reagent adsorption to components contained in potash ores.

INTRODUCTION

A comprehensive literature survey of non-conventional magnetic separation processes was carried out in order to supplement the on-going research project at CCP and to evaluate the applicability of the processes in the potash industry. It is generally regarded that the conventional magnetic separation depends on the inherent magnetic susceptibility of the material to be separated. In the mineral processing industry, various types of magnetic separation machines and processes are utilized, which can be classified depending on the types of magnets, field strength and field gradients employed. Only a few minerals are commonly separated magnetically, however, since the introduction of a high-gradient, high-intensity magnetic separator, the applicability of the process has been growing steadily in the field of non-metallic processing, including coals. Recently developed separators with high-intensity, high-gradient fields can remove strongly paramagnetic materials, but is inefficient in removing weakly paramagnetic or diamagnetic minerals.

In this survey the non-conventional magnetic processes are grouped by (i) use of magnetic fluid, and (ii) magnetic coatings. The first group can be classified as:

(a) magnetogravimetric separation
(b) magnetohydrostatic separation
(c) magnetohydrodynamic separation

depending on the type of paramagnetic fluids (electrolyte or colloidal magnetic suspension) and the use of magnetic and electric fields.

The second group utilizes chemical or physical surface treatment to create or increase the magnetic susceptibility of one or more components in a mixture. This phenomena can be achieved by "attaching" magnetic particulate (ferromagnetic materials) or by coating certain mineral phases with iron carbonyl followed by conventional magnetic separation.

MAGNETIC FLUID AND LIQUID

A magnetic fluid is a stabilized suspension of magnetically susceptible particles in a carrier fluid. This fluid contains three basic elements - particles, carrier and dispersing agents. The ultra-fine particles should have high magnetic susceptibility and high saturation magnetization. The carrier liquid may be water, hydrocarbon, fluorocarbon or other liquid having non-magnetic properties, and the dispersing agent must be capable of being absorbed on the surface of the particles and of being solubilized by the carrier liquid. This forms a protective layer on the particles to prevent collision and agglomeration. Oleic acid is commonly used for stabilizing hydrocarbon-based magnetic fluids.

Two important characteristics of magnetic fluids are utilized in the mineral processing system. One property of the magnetic fluid is the ability to impart magnetic susceptibility to normally non-magnetic materials when it is attached to the surface of certain mineral phases.

Another property, variable fluid density induced in the magnetic field, is used to levitate different density materials. This separation can be termed as magnetic sink-float separation. In this instance, not only magnetic fluids (colloidal suspension of magnetic particulates), but also true magnetic liquids are used. Each separation scheme is discussed in the following sections.

SEPARATION BY MAGNETIC COATING

Magnetic Particulates (Magnetic Carrier)

In this process, selective coating of minerals or metallic particles with colloidal, chemically-precipitated magnetite is used prior to magnetic separation. It is well known that modification of mineral surfaces by the adhesion of fine particles of a different kind may influence the response of the mineral to separation processes, especially flotation. If the absorbed species is magnetic, the selectivity in the magnetic separation may be improved. The selectivity of the magnetic particle coating is normally obtained by controlling the surface properties of the particles, the zeta-potentials and hydrophobicity

is altered by pH adjustment and the addition of surfactants such as sodium oleate or dodecylamine. Shubert[1] described a process of separating sulphides from silica and calcite and also coal from ash by coating and agglomerating the materials with a magnetic fluid. The magnetic fluid is made from an ultra-stable colloidal suspension of magnetic particles in liquid carriers such as hydrocarbons, fluorocarbons, silicone oils and water. The treated pulp is subjected to a magnetic separator and a magnetic fluid-wetted concentrate is obtained. The minerals should be conditioned with chemicals to render the surfaces of particles hydrophobic and organophylic, to enhance attachment of the magnetic fluid.

In Shubert's test with coal, a kerosene-based fluid was used to magnetize the organic matter, while the inorganic matter remained in its normal non-magnetic state. Recovery of organic matter was achieved with an electromagnet with a field strength of about 100 gauss. Shubert claimed this process could be used for sulphides, oxides and carbonaceous ores. Actually, the Shubert patent is an improvement of the old Murex process, in which unstable suspensions of coarse magnetic particles are used.

The Murex process[2] uses a combination of magnetic separation with the differential-oiling phenomenon. In this process, the oil is first loaded with powdered magnetite, then mixed with aqueous pulp and the whole slurry is presented to a magnetic field for separation. The oil-coated minerals are attracted to the magnet because of the magnetite in the oil coating. This process has been used in several sulphide mineral processing plants.

The fluid-enhanced magnetic separation tests of coal have shown[3,4] that the untreated coal was not amenable to clean with a high-intensity induced roll separator, but the treated coal responded very well with the same device. This process is also used in the kaolin industry to refine the crude clay[5-9]. The clay slurry is seeded with a precipitate of Fe_3O_4 and subjected to a magnetic field to magnetically flocculate titaniferous contaminants in the clay together with the magnetic Fe_3O_4 for removal by magnetic separation.

The theoretical aspect of magnetic separation using chemically-precipitated magnetite was discussed recently[10]. The selectivity of coating is controlled

by the surface properties of the particles. The zeta-potential, and hydrophobicity are altered by pulp pH and the addition of surfactants such as sodium oleate or dodecylamine. A good separation scheme was obtained for artificial mixtures of apatite-calcite, quartz-fluorite and metallic lead-copper. It was concluded that the selective magnetic coating process is applicable to the treatment of any mixture for which the surface properties of the constituents can be sufficiently modified.

The commercial feasibility of the process was discussed using ground magnetite for separating naturally-occurring phosphate ore containing calcite[11]. It was found that phosphate concentrates close to the theoretical maximum of 25-26% P_2O_5 can be achieved at recoveries of over 80% from a feed of 8% P_2O_5, using 50 kg/T magnetite and 2.8 kg/T sodium oleate. The ground magnetite (-250 +10 lb) used as magnetic carrier can be recovered for recycling.

A different approach in modifying the surface property was investigated for the treatment of a finely disseminated alunite in quartz matrix[12]. In this study, a selective flocculation technique is used for separating alunite from quartz. The ore is ground in the presence of dispersant. The deslimed pulp is slurried with magnetite (-5u) at a concentration of 1% by weight of the ore. The magnetite-laden slurry is then treated with 0.25 lb/T non-ionic polyacrylamide flocculant. At this stage, the quartz particles are selectively co-flocculated with magnetite. The slurry is then separated with a high-gradient separator having 0.1 tesla field strength and made of stainless steel wool. The results showed that magnetic process is superior to flotation.

Magnetic separation using magnetic particulates (precipitated or ground magnetite) as selective carrier have shown that the efficiency of separation is basically dependant on the surface properties of the mineral assemblages. The magnetic particulates can be used as is or stabilized in a suspension containing ionic surfactants.

In view of this preferential particle co-aggulation, it may be worth investigating the feasibility of the technique in potash processing, since two basic ionic collectors have preferential affinity to mineral components, namely the amines for sylvite and sodium oleate for halite and insolubles.

However, it should be noted that the efficacy of ultra-fine magnetic particles in the brine system may be poor due to high corrosion rate. Furthermore, the presence of ultra-fine slimes should be considered in terms of reagent adsorption and fouling of the magnetic medium.

Chemical Magnetic Coating-Carbonyl Process

This process involves dry-grinding, heating, carbonyl treatment and magnetic separation. The dry-ground ore is heated to 100-200^{o}C, and exposed to vapors of iron pentacarbonyl, which decomposes preferentially on certain types of minerals. This process is known as the Magnex process[13,14,15], developed by Hazen Research for the treatment of pyritic coal, and is based on the selective decomposition of iron pentacarbonyl on pyrite and ash surfaces in the presence of coal. The reactions proposed are:

on ash: $Fe(CO)_{5(g)} \text{-----} > Fe_{(s)} + 5\ CO_{(g)}$

on pyrite: $Fe(CO)_{5(g)} + FeS_{2(s)} \text{-----} > 2\ FeS_{(s)} + 5\ CO_{(g)}$

It was suggested that the selectivity of iron carbonyl occurs on the more active surface of pyrite and ash compared with coal.

Another patent[16] described that sulphide ores can be beneficiated by reaction with iron pentacarbonyl. Artificially prepared sulphide minerals (galena, sphalerite, molybdenite and others) were used in these tests.

Meech has studied the reaction system between iron pentacarbonyl and chrysocolla in terms of temperature, gas composition and flow rate to elucidate the activation energy and reaction kinetics[17].

Although some promising and effective test data were claimed, it is believed that there are some obstacles, including dry grinding, moisture reduction requirements, dealing with highly toxic carbonyl gases and handling of particles coated with iron which tend to agglomerate magnetically.

SEPARATION WITH MAGNETIC FLUIDS (Sink-Float Separation)

Conventional magnetic separation relies on the inherent magnetic susceptibility of the mineral to be separated. However, when the medium of separation rather than the separated particles are magnetized, a gravity separation results. The magnetic force imparted in the medium generates a levitation force, and hence is able to segregate non-magnetic particles according to their specific gravity.

The apparent density or the levitation force can be varied either by changing the concentration of the fluid or the magnetic field gradient. This type of separation is categorized as magnetogravimetric, magnetohydrostatic or magnetohydrodynamic[18,19].

Magnetogravimetric (MGM) Separation

This technique was developed mainly by the staff at the US Bureau of Mines. A colloidal suspension of a ferri or ferromagnetic substance is used as the separation medium. The history and the theoretical development work of the magnetic suspension can be found in the literature[19-21]. It should be noted that both magnetogravimetric and magnetohydrostatic separations operate on the same principle, but use different magnetic media.

Early experimental work[21] using colloidal magnetite stabilized in kerosene in the presence of oleic acid have shown that the magnetic levitation force created in the magnetic fluid placed in a non-uniform field was capable of separating various density materials. A bench-scale MGM separator has been used to separate non-ferrous metals in incinerator residue[22] into three fractions according to density. The bulk of magnetic fluid adhering to the separated particles was recovered by floating on water and skimming off with the aid of moving magnets.

Operation of a semi-continuous unit built with a 4.5 ton electromagnet was reported[23]. Magnetic fluids having magnetization values from 100 to over 400 gauss prepared by varying the quantity of magnetite dispersed in the kerosene carrier were used. The variables examined included feed rate (100-2000 kg/h), discharge mode (chute or conveyor), magnetization and fluid. It showed that the

unit was capable of separating non-ferrous metals from automobile and appliance shredders and mixed metal scraps. Also tested was a sample of diamondiferous jig concentrates.

Although there exists some promising results of the MGM separations, information regarding the interactions between the magnetic fluids and potash ore are not known, and the presence of fine material in the feed may have an important bearing on the separation.

Magnetohydrostatic (MHS) Separation

In this system of separation, a paramagnetic liquid (or melt) replaces the magnetic fluids in MGM separations. The process was pioneered in the early 1960's by Russian scientists, and introduced by Andres to the west in 1975[18]. In the MHS system, the magnetic moment and magnetic susceptibility of a paramagnetic salt solution are much smaller than those of typical magnetic fluids discussed above. Relatively high magnetic susceptibilities can be obtained by the use of highly soluble salts of Mn, Fe and Co[18,24].

Preliminary test work using the laboratory scale MHS separator for concentrating gravity gold concentrates has been reported[25]. Results shows that a high-grade gold-containing concentrate could be obtained with 90% recovery. Parsonage[26] studied the feasibility of using various paramagnetic liquids for separating a number of mixtures of non-magnetic minerals, e.g. pyrite-sphalerite-galena, cassiterite-scheelite, zircon-rutile, and copper-lead. The results showed that near-perfect separations are possible, provided the minerals are liberated. However, acid or water-soluble minerals need special attention in the use of the paramagnetic liquids, since most of the liquids are water-based and acidic.

A pilot unit having capacity of 300 kg/h throughput was tested on a continuous basis for separating a galena and barite mixture (-1.7/+0.8 mm)[27]. A manganous chloride solution was used as the magnetic medium. Variables studied were field strength, liquid flow rate, feed rate and size. Although near-perfect separation was obtained, the application of the MHS separation to commercial operation depends on the economics and the availability of alternate

treatment methods. Based on the above, the economic and technical aspects of the MHS separation have shown[28] that the major costs of treating materials in an MHS separator would consist of labour, magnetic liquid losses and the power cost to drive the magnetic circuit. Liquid regeneration is needed to keep the costs to a minimum. It was concluded that its principal area of application may be in the final upgrading of concentrates of high value minerals, and other materials not amenable to treatment by conventional methods.

A new mineral separation process using the basic principles of MHS separation has been reported recently[28]. The so-called MC process can be used in an alternate mode for the separation of particles based on weak magnetic property differences or for separation based on the combination of magnetic properties and specific gravity by rotating the separation chamber. According to test work performed with various mixtures and natural ores and concentrates, the process is capable of treating materials having small density (0.3 g/cm^3) or susceptibility (36 x 10^{-6} emu/cm^3). differences, and fine particles (down to 5 microns).

Magnetohydrodynamic (MHD) Separation

The MHD separation is based on the excitation of an electromagnetic force in an electrolyte by a crossed electric and magnetic field[18,19]. Since the electrical conductivity of electrolyte solutions is dependent on their concentration, it is necessary to select the concentration that provides maximum conductivity. Much of the development work on MHD separation has been carried out by Russians and East Germans[18]. Treatment of coal, manganese, iron and gold ores have shown that the MHD separation is particularly favorable for the recovery of particles that are both conducting and dense. MHD separations with capacities of 5 t/h and 50 t/h were reportedly tested in coal preparation and tin ore industries, respectively[18].

The theoretical aspect of the MHD separation process was examined in terms of fluid density, particle size and other variables[30]. The separator was utilized for carnalite containing potash ores in a specially prepared magnetic fluid containing $MnCl_2$ in brine. It was concluded from the theoretical and laboratory tests that the separation of carnalite (light material) from salts (heavy) was feasible. No follow-ups are available.

CONCLUSIONS AND RECOMMENDATIONS

The literature survey of non-conventional magnetic separation using magnetic coatings and magnetic fluids have shown that although there are numerous publications dealing with the theory and development of the processes, no true commercial operation have been introduced.

The magnetogravimetric (MGM), magnetohydrostatic (MHS) and magnetohydrodynamic (MHD) separation processes have many promising features, however, the processes have a number of serious drawbacks:

(a) It is not readily applicable to fine particles. Long retention times lower the capacity of a given machine.

(b) The narrow pole gap of the high magnetic field also results in relatively low capacity.

(c) The process utilizes relatively expensive reagent (colloidal magnetite or $MnCl_2$) as separating medium. Although recovery and recycling of the medium has been considered, the losses of reagents will constitute an important part of the operating costs.

(d) Since the processes are only for non-magnetic or weakly-magnetic particles, the presence of high magnetic-susceptible materials will eventually contaminate the products.

Therefore, any commercial application will necessarily be in special circumstances, such as very high value, coarse and perfectly-liberated materials.

Also, the iron pentacarbonyl process may have shown some merits in a number of instances, however, the highly toxic nature of the process has its own limitations.

The magnetic particle coating process seems to be the only process worth considering in the potash operation. However, the highly-corrosive nature of the brine and the presence of ultra-fine water insoluble slimes in the system may cause problems with the process.

REFERENCES

1. Shubert, R.A. (to Maryland Patent Development Co.), Magnetic separation of particular mixtures, U.S. Patent 3926789 (16 December 1975).

2. Taggart, A.G., Handbook of mineral dressing, John Wiley and Sons, New York, 1945, Ch. 12, p 50.

3. Sladek, T.A. and Cox, C.H., Coal beneficiation with magnetic fluids, Coal Process Tech. 5, p. 19-23, 1979.

4. Sladek, T.A. and Cox, C.H., Coal preparation using magnetic separation, Vol. 4, Evaluation of magnetic fluids for coal beneficiation. Report 1980, EPRI-CS-1517.

5. Nott, A.J. (to Anglo-American Clay Corp.), Magnetic beneficiation of clays utilizing magnetic particulates, U.S. Patent 4087004 (2 May 1978).

6. Nott, A.J. (to Anglo-American Clay Corp.), Magnetic beneficiation of clays utilizing magnetic particulates, U.S. Patent 4125460 (14 November 1978).

7. Nott, A.J. and Price, W.M. (to Anglo-American Clay Corp.), Magnetic separation of minerals utilizing magnetic particulates, U.S. Patent 4219408 (26 August 1980).

8. Nott, A.J. and Price, W.M. (to Anglo-American Clay Corp.), Separating metallic minerals utilizing magnetic seedings, U.S. Patent 4225425 (30 September 1980).

9. Nott, A.J. and Price, W.M. (to Anglo-American Clay Corp.), Magnetic beneficiation of clays utilizing magnetic particulates, U.S. Patent 4225426 (30 September 1980).

10. Parsonage, P., Selective magnetic coating for mineral separation, Trans. I.M.M., 93, p. C37-44, 1984.

11. Parsonage, P., The recovery of phosphate from carbonaceous gangue by selective magnetic coating - a novel method of mineral separation by control of surface properties, in Proceedings, XVth Inter. Min. Process Cong., Cannes, France, June 2-9, 1985, Vol. III pp 347-356.

12. Hwang, J.Y., Kullerud, G., Friedlaender, F.J. and Takayasu, M., A method for alunite beneficiation, paper presented at the SME-AIME Annual Meeting, N.Y., Feb. 24-28, 1985, paper no. 85-11.

13. Kindig, J. and Turner, R.L., Dry chemical process to magnetize pyrite and ash for removal from coal, paper presented at the AIME Fall Meeting, Denver Colorado, September, 1976, No. 76F-306.

14. Porter, C. and Goens, D., Magnex pilot evaluation - a dry chemical process for the removal of pyrite and ash from coal, paper presented at the AIME Fall Meeting, St. Louis, MO, October, 1977, No. 77-F-352.

15. Kindig, J. (to Hazen Research Inc.), Removal of impurities from coal, U.S. Patent 4098584, 4 July 1978.

16. Kindig, J. and Turner, R.L. (to Hazen Research Inc.), Process for beneficiating sulphide ores, U.S. Patent 4239529, 16 December 1986.

17. Meech, J.A., Upgrading chyrosocolla ores with iron pentacarbonyl, Trans. I.M.M., 89, p. C152-160, 1980.

18. Andres, U., Magnetohydrodynamic and magnetohydrostatic separation in the magnetic field. Minerals Sci. Eng. 7(2), p. 99-109, 1975.

19. Khalafalla, S.E., Beneficiation with magnetic fluids - magnetic separation of the second kind, Min. Process and Ext. Met. Review, Vol. 2, p. 21-25, 1985.

20. Iammantino, N.R., Magnetic liquids launched, Chem. Eng. P. 74-76, Jan. 21, 1974.

21. Khalafalla, S.E., Magnetic fluids, Chem. Tech. p. 540-546, September, 1975.

22. Reimers, G.W., Rholl, S.A., Snyder, R.W. and Khalafalla, S.E., Cell design to separate non-ferrous metals in incinerator residue with magnetic fluids, Material Scie. and Eng. 15, p. 129-135, 1974.

23. Khalafalla, S.W. and Reimers, G.W., Beneficiation with magnetic fluids, U.S.B.M., R.I. 8532, 1981, p. 31.

24. Anders, U., Potentialities of magnetohydrostatic separation using solutions of salts of rare earth elements, J. of the S. African Inst. of Min. and Met., October, 1975, p. 113-116.

25. Lin I.J. and Finkelstein, N.P., Magnetohydrostatic separation of gold from gravity concentrates, National Inst. for Metallurgy, S. Africa Report No. 1747, July 1975.

26. Parsonage, P., Small scale separation of minerals by use of paramagnetic liquids, Trans. I.M.M., 86, B43-46, 1977.

27. Parsonage, P., Factors that influence performance of pilot-plant paramagnetic liquid separators for dense particle fractionation, Trans. IMM 89 C166-173, 1980.

28. Parsonage, P., Commercial application of solids separation using paramagnetic liquids : economic and technical considerations, Warren Spring Laboratory Report LR278(MP), 1978.

29. Walker, M.S. et al, A new method for the commercial separation of particles of differing densities using magnetic fluids - the MC process, in Proceedings, 15th IMPC, Vol. II, Cannes, France, 1985, p. 307-316.

30. Madai, E. and Melzer, U., On MHD separation in industry of potassium, Neue Bergbau Technik 2(3), 1972.

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PROJECT PART II

PILOT PLANT STUDIES ON

DRY MAGNETIC SEPARATION OF CLAY

FROM SYLVITE AND HALITE

Wey Lee

PCS Technical Services

ACKNOWLEDGMENTS

This project has been co-funded by CANMET, Department of Energy, Mines and Resources, and the Saskatchewan Potash Producers Association. We would like to thank Dr. Bo Arvidson of Ore Sorters for his help and useful discussions; Larry Buckle and Steve Mason of CCP for their participation in pilot plant testing suggestions and useful discussions; Pilot Plant staff: Tom Boryski, Jim Stinson, Roberta Lafontaine and Jana Nguyen; and above all, Ray Casavant and Gerry Zurevinski, who have carried out the test work successfully throughout this project.

ABSTRACT

A one-meter, 100 mm diameter, single-stage Permroll dry magnetic separator was tested at the PCS Pilot Plant with various potash size fractions and feed rates. Data of potash recovery and clay rejection with respect to weight percentage of magnetic (splitter position) were correlated. Single-pass results indicate that the 3 x 6 mesh fractions performed best up to 8 tph judging from the KCl recovery and clay rejection. Throughput was governed by particle layers and uniformity of the particles' distribution on the belt and seemed limited to the monolayer. Particle layers' effect and up to 1" particle size was also investigated and discussed.

SOMMAIRE

Un séparateur électro-magnétique Permroll (1 m de largeur x 100 mm de diamètre) a été testé à l'usine pilote de Potash Corporation of Saskatchewan, sur de minerais potassiques de diverses granulométries et à différents taux d'alimentation. Une corrélation entre le taux récupération de la potasse, le rejet des argiles, et l'intensité du champ magnétique a été établie. Pour les particules de 3 à 6 meshes, les résultats sont satisfaisants jusqu'à un taux d'alimentation de 8 tonnes/heure. La capacité du séparateur est déterminée par l'uniformité de distribution et le nombre de couches de particules sur la courroie. Les meilleurs résultats sont obtenus avec une seule couche de particules. Les effets de couches et de granulemétrie (particules jusqu'à 1 pouce de diamètre) ont été étudiés, et sont discutés dans ce rapport.

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1.0 INTRODUCTION

Clay minerals associated with potash ores in the Patience Lake Member of the Prairie Evaporite present a prominent problem in processing and environmental aspects of potash production. Underground removal of clays liberated by mining would minimize dust content of the produced ore, improve hoisting capacity and minimize further expansion of surface tailings disposal areas. On the surface, a low clay content mill feed would require less scrubbing or desliming capacity. This would save on maintenance, power, reagents, operating labour, and improve recovery. Furthermore, particle attrition would be reduced resulting in lower materials handling and drying costs. Lower clay content in slimes thickeners would simplify circuit performance and decrease power consumption and maintenance costs.

Recently a report (1) established by Central Canada Potash (CCP) showed that a high intensity, high gradient permanent magnet roll separator, Permroll (Ore Sorter Inc.), appeared capable of removing clay from potash ore. CCP's report (1) covered an in-depth investigation of the Permroll performance on individual ore size fractions, such as 6, 8, 10, 14, 20, 28, 35, 45, 45, 65 and 100 mesh, as well as on various combinations, such as 6x8, 8x14, 14x100, and -100 mesh, and 6x100 and 6x200 mesh combinations. Several circuit configurations of practical interest, such as: single stage/single pass; series multiple stage; single stage/reprocessing of magnetics; series stage/ reprocessing of magnetics; series stage/ screening of magnetic middlings prior to reprocessing; and a three-product circuit, were investigated. Clay liberation studies were also reported. However,

these test results were performed with a 3-inch diameter and 4-inch wide beltless laboratory unit which was limited to batch processing, low throughput (nominal at 0.8 tph), and particle sizes smaller than 3 mesh.

This is a follow-up investigation from laboratory unit to pilot scale operation with a one-meter long, 100 mm diameter single stage Permroll dry potash separator. The object of the studies is to investigate the throughput capability of the separator and the limit of the separator on particle size.

CCP and PCS Lanigan feedstock was tested throughout this work.

2.0 PILOT PLANT PRODUCTION PERMROLL MAGNETIC SEPARATOR

2.1.1 Production Permroll Magnetic Separator

The production Permroll magnetic separator is a one-meter long, 100 mm diameter single stage separator. It is designed on an interchangeable modular concept and is comprised of the following components:

a) A triple head vibrating pan feeder and support bracket mounted on the machine's upper Permroll module, as shown in Figure 1.

b) One Permroll module consists of a short conveyor belt, belt tensioning system and split hopper, as shown in Figure 2. Figure 3 is a close-up of the unique patented matrix of the one-meter long, 100 mm diameter Permroll which was used throughout in this test work.

Figure 1. Feed bin, vibratory feeder pan and belt.

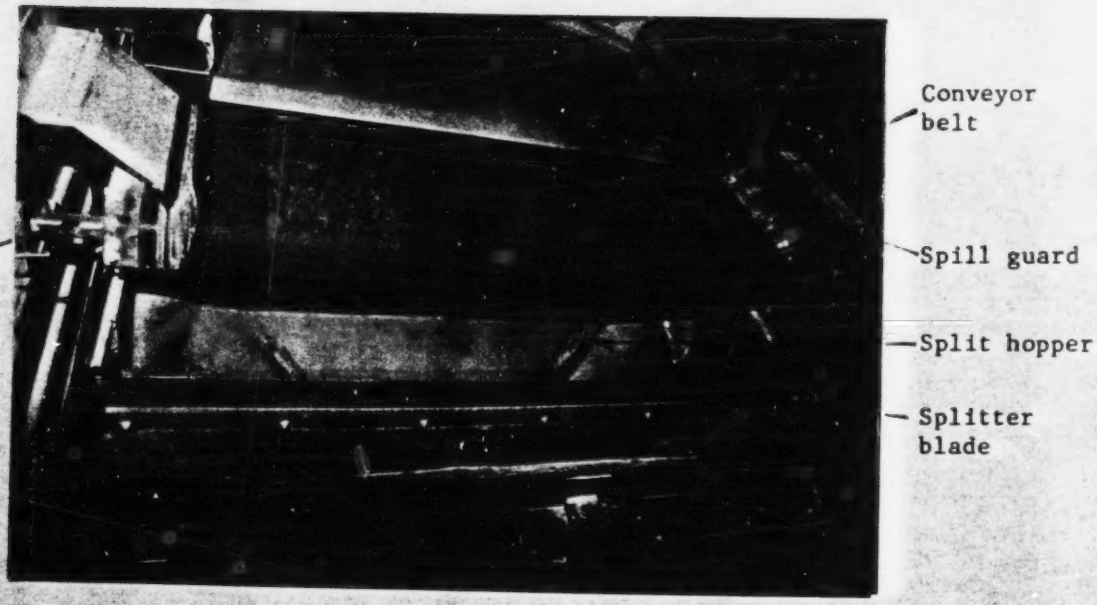

Figure 2. Splitter blade and spill guards.

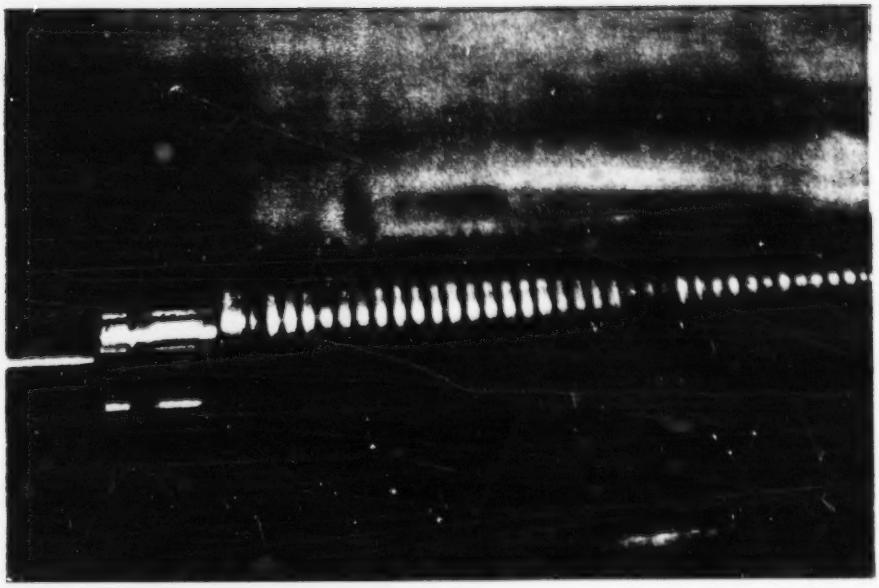

Figure 3. The 100 mm diameter and 1000 mm long Permroll. (Magnet is neodymium iron and boron alloy)

c) A drive module with a D.C. variable speed motor which is directly coupled to the shaft of the Permroll (Figure 2).

d) A frame which supports the Permroll module vibrating feeder.

e) An electrical control box which houses the vibratory feeder and D.C. motor control.

The production Permroll magnetic separator was rented for one and a half months from Ore Sorters Inc. It was received at the PCS Pilot Plant in a dismantled form and was then assembled, commissioned and verified with a small amount of sample to make sure that the separator was operated properly under the supervision of Dr. Bo Arvidson of Ore Sorters

In addition, a feed bin, two discharge chutes and a system frame were built at the PCS Pilot Plant to provide a set-up for continuous operation (Figure 4). The feed bin (Figures 1 & 5) was used to distribute the tested ore particles evenly over the entire feeder tray width (Figure 6) and not simply heap them in the centre. In front of the feed bin was an adjustable slide gate which was used to regulate the feeding rate. The system frame supported the Permroll separator, the feed bin, and the one-ton capacity field hopper which kept the feed bin full during operation.

The Pilot Plant separator was tested from November 2 to December 18, 1987.

2.1.2 Operation procedures

Operation procedures of the Permroll separator are simple, and can

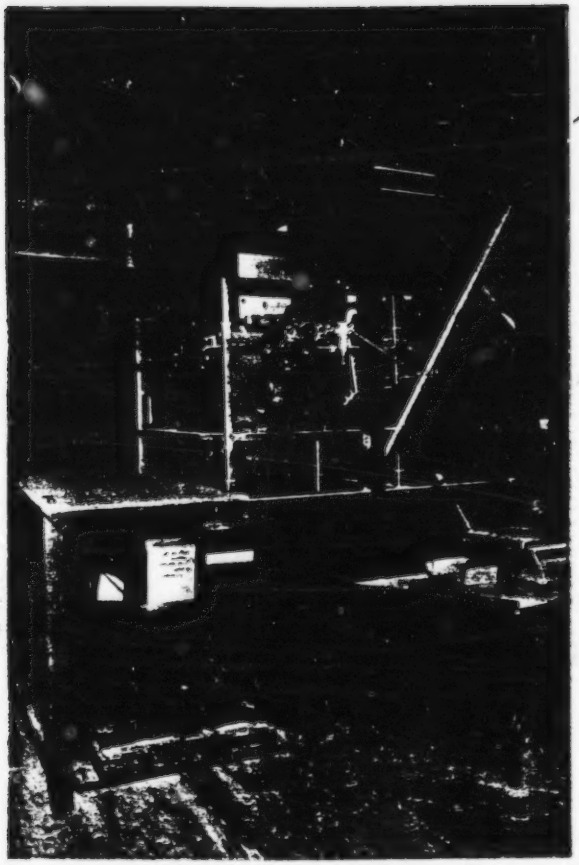

Figure 4. Pilot plant single stage Permroll magnetic separator set-up (1 ton hopper was not shown).

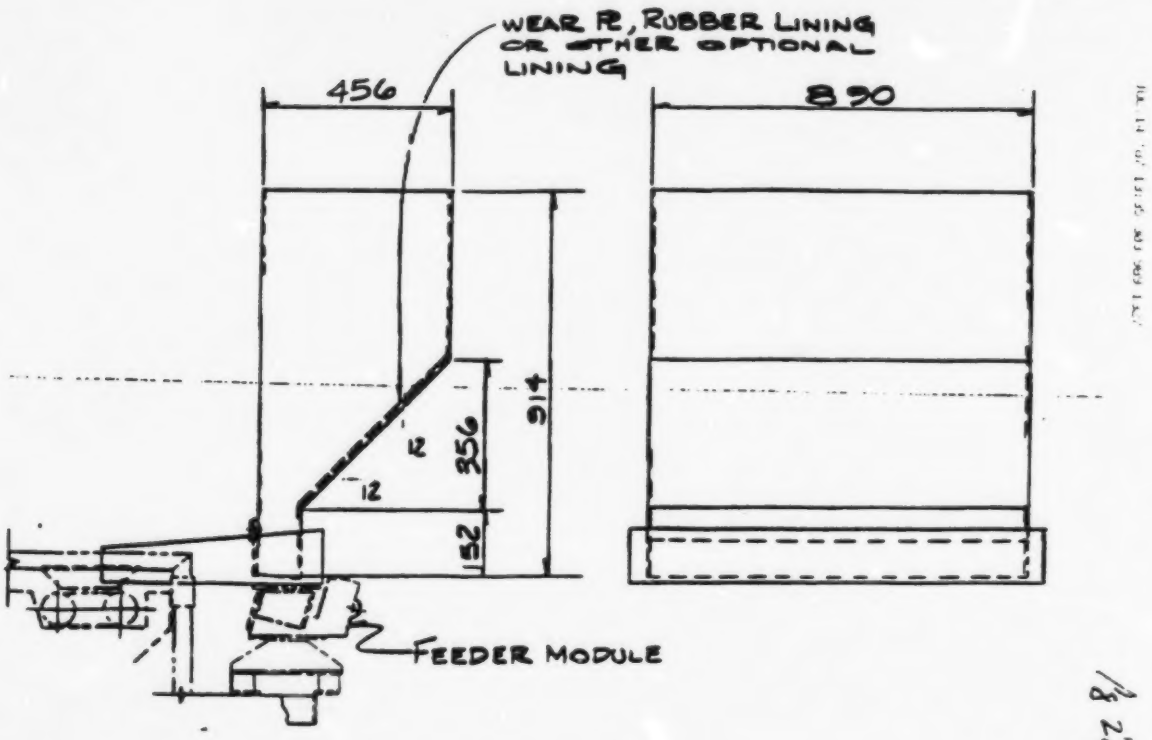

Figure 5. The ore feed bin.

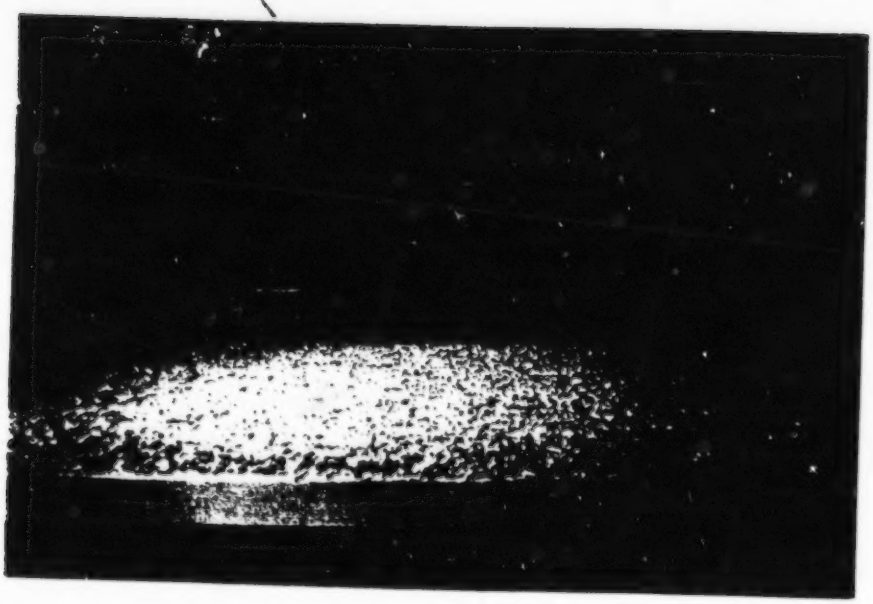

Figure 6. The feed bin and adjustable slide gate.

be summarized as follows:

1) Feed was prepared and charged into the one-tonne feed hopper which was then positioned securely on top of the system frame. Ore was then discharged from the one-tonne feed hopper into the feed bin. For a small batch operation, feed ore can be charged into the feed bin directly.

2) The belt speed was then set at the appropriate dial to obtain the desired feed rate. The belt speed is largely dependent on the magnetic properties of the particles and the particle size to be separated, and a few test results should provide an adequate operation range. The rpm of the Permroll was measured by a tacheometer.

3) Setting the splitter blade position. The splitter blade position, which governs the product split into magnetic and non-magnetic fractions, was adjusted simply by moving the splitter adjusting lever as shown in Figure 7. A graduated scale was provided against which the adjusting level could be set and then locked. As it was impossible to set the blade position based on visual observation of the blade cutting into the falling ore stream, multi-tests with various positions were necessary in order to find the appropriate blade position for a feed rate and size fraction.

4) The feeder control was switched to the appropriate setting and the vibrator feeder distributed ore particles uniformly over

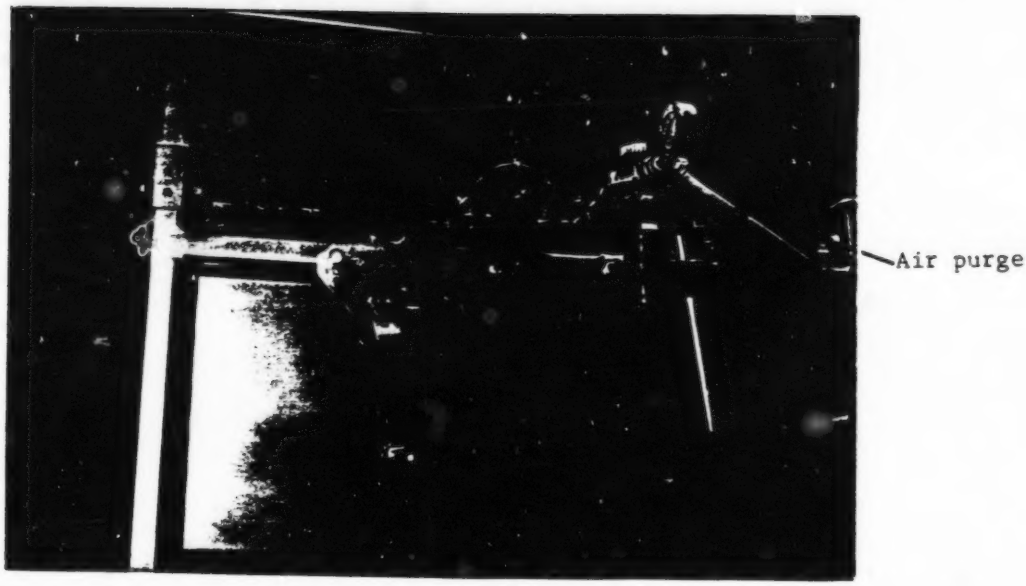

Figure 7. The splitter blade adjusting lever.

the pan and then over the entire roll length, as shown in Figure 8. The feeder was then stopped and was ready for a new test. During the testing, a sample of the non-magnetic stream was cut across the one meter length, while a sample of the magnetic was cut from the discharge stream.

3.0 RESULTS AND DISCUSSION

Table 1. Summary of Feedstock and Size Fraction

Feedstock	CCP	Lanigan	
		Low Clay	High Clay
Size fraction, mesh	6 x 28	6 x 28	6 x 28
	3 x 6	3 x 6	3 x 6
		7/16" x 3	7/16" x 3
		+28	1" x 3
		10 x 20	

Table 1 summarizes the feedstock and size fractions which were tested and discussed in this report. The +28 mesh and coarser size fractions were used, as major weight and clay (WI) were distributed in +28 mesh and coarser size fractions than in the fines, as shown in Figures 9 and 10. The CCP feedstocks were prepared at the CCP facility and tested at the PCS Pilot Plant by L.Buckle and S.Mason, with the assistance of R.Casavant from PCS. The Lanigan feedstock, low and high clay ore, was prepared at the PCS Pilot Plant and tested by R.Casavant, G.Zurevinski and W.Lee. Assays, KCl and WI (water insoluble or clay) of magnetics/ non-magnetics, were done with PCS x-ray spectroscopy and the KCl and WI of head sample (feed) were calculated from metallurgical balances.

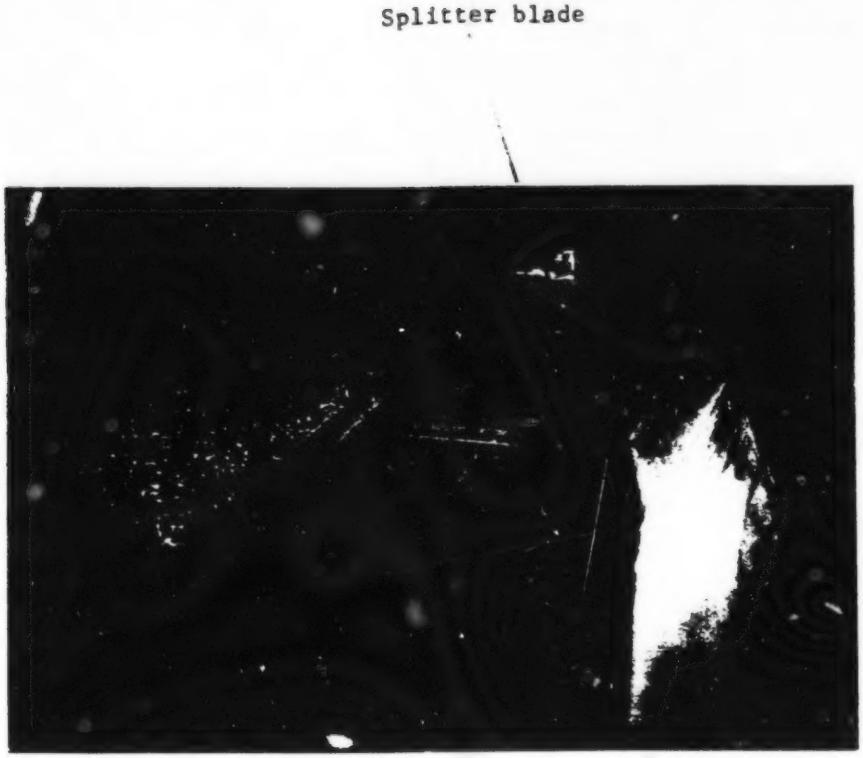

Figure 8. Ore distributing uniformly over the pan prior to dropping into belt.

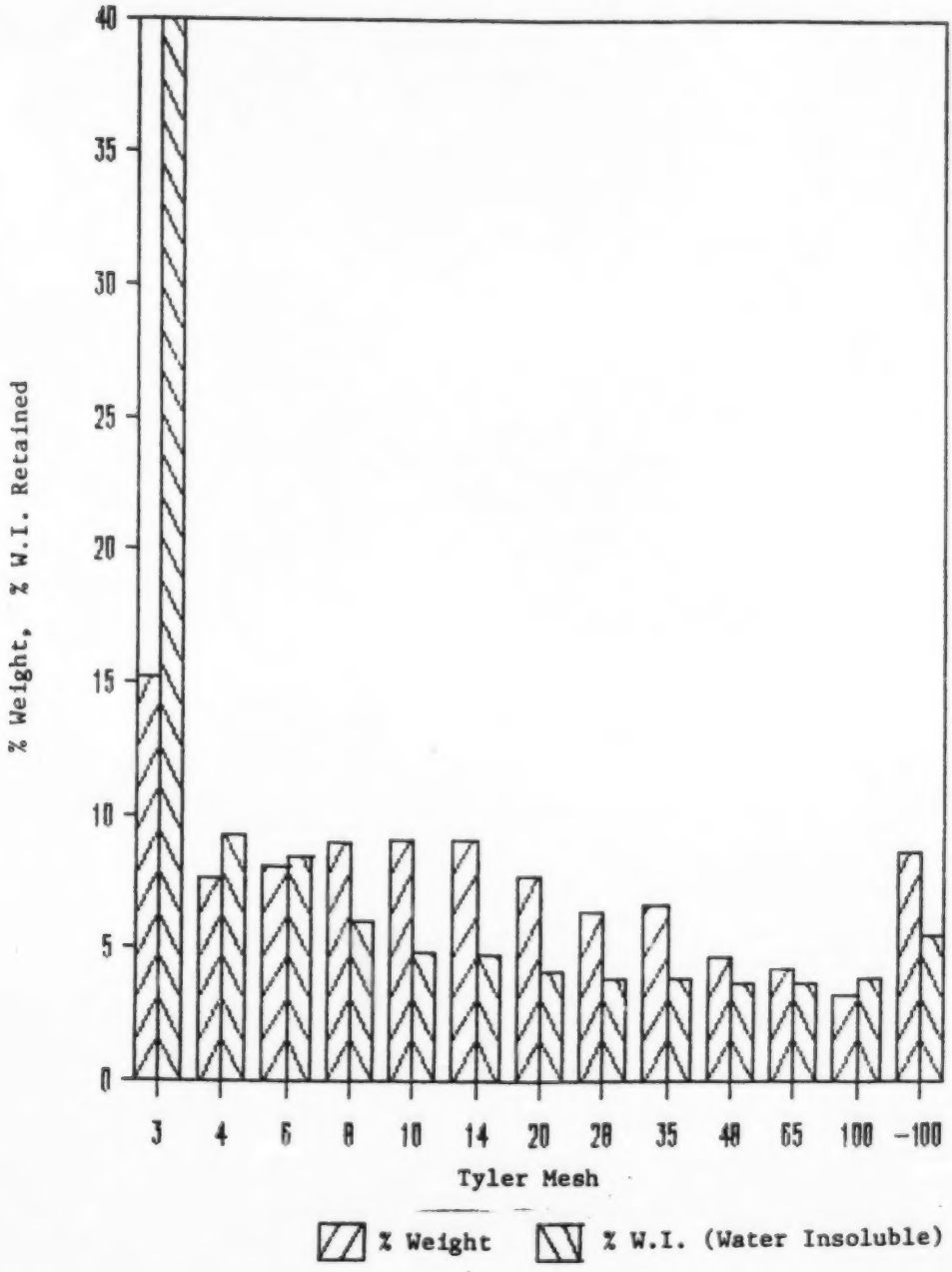

Figure 9. Weight and insol distribution - A sample from PCS Lanigan Division mill feed.

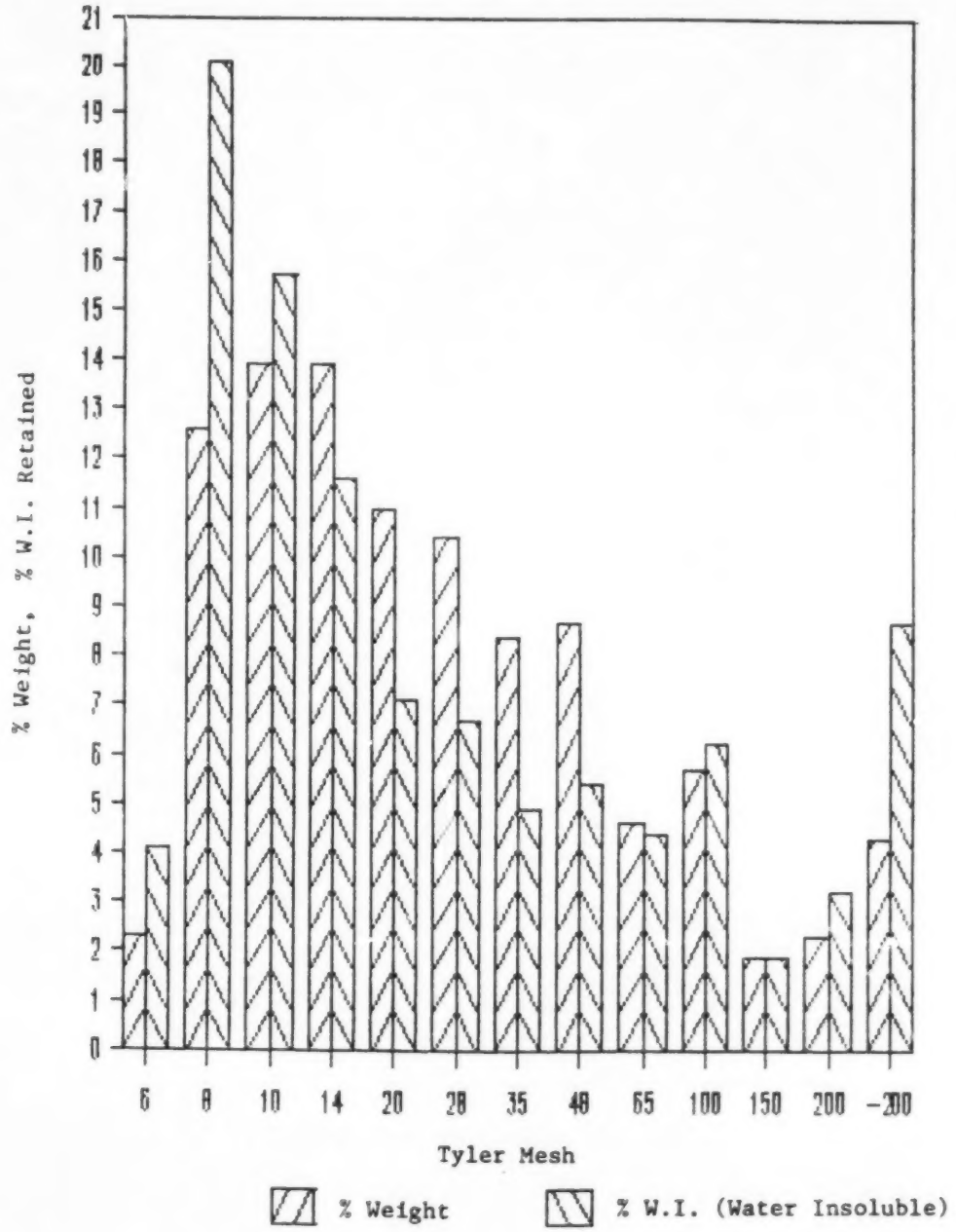

Figure 10. Weight and insol distribution - CCP typical ore fraction analysis (After W.Hrynewich (1)).

Test results of CCP's 6 x 28 mesh and 3 x 6 mesh fractions at various feed rates are summarized in Tables 2 and 3 respectively, while those of PCS are summarized in Tables 4, 5 and 6 for Lanigan high clay ore, and Tables 7, 8 and 9 for Lanigan low clay ore respectively. In each Table, % KCl and % WI of feed, magnetic and non-magnetic streams are shown, the % magnetic and % non-magnetic split, the recovery of KCl and WI rejection in non-magnetic and magnetic are also tabulated.

As discussed in 2.1.2, the splitter blade position decided the percentage split between magnetic and non-magnetic streams. Because the splitter blade position could not be set visually to obtain a predictable percentage of WI rejection in the magnetic stream, and percentage of KCl recovery in the non-magnetic stream, the test therefore was performed in various splitter positions using the graduated scale (Figure 7) as a reference to control the percentage of splitting. For example, a reading of 82 mm and 88 mm on the graduated scale would correspond to a 19/81 and 4.4/95.6 magnetic/non-magnetic split respectively for a sample of -7/16" +3 mesh fractions at 5.0 tph feed rate; higher readings on the graduated scale resulted in lower weight percentage in the magnetic stream.

The performance of the separator for a size fraction at various feed rates can be justified by the best % KCl recovery in non-magnetics and % WI rejection in the magnetics.

3.0.1 Results and Discussion - CCP Feedstock

Figure 11 shows a typical correlation between the % KCl recovery in non-magnetic, % WI rejection in magnetic, and the weight % magnetic (splitter gate position) for 6 x 28 mesh fractions. As can be seen, at low tonnage, 2 to 5 tph, the % KCl recovery in the non-magnetic decreased slowly, while the % WI rejection in the magnetic increased rapidly with the increase of the magnetic split up to about 12-13%. However, further increasing the magnetic split did not reject more WI in the magnetic but, in turn, the % KCl recovery in the non-magnetic dropped. At high tonnage, 9-12 tph, the % WI rejection in the magnetic was vey poor, around 5-10%, while the % KCl recovery in the non-magnetic remained good. Figure 12 shows the results of CCP 3 x 6 mesh fraction feedstock tested at 7.7 tph to about 13 tph feed rate. It appears that the % KCl recovery in the non-magnetic stayed above 90%, up to about 12% magnetic weight split, and dropped to about 80% as the weight split increased to 26%. The % WI rejection in the magnetic performed better for the 3 x 6 mesh fraction than that of the 6 x 28 mesh fraction at high tonnage. Run 42 showed the best results of the 3 x 6 mesh fraction; at 8.7 tph feed rate, the % KCl recovery and the % WI rejection were 91.4% and 46.2% respectively, while % KCl upgraded from 32.3% to 33.3% and % WI reduced from 9.2% to 5.6% (Table 2). However, at a 13.8 tph feed rate (Run 47), the % KCl recovery and % WI rejection reduced to 88.1% and 38.9% respectively at a 13.6% magnetic weight split. Note that wherever dotted lines appear on these, figures were not obtained from regression but they rather illustrate the possible trending for ease of observation.

Table 2. Summary of test results - CCP 3x6 mesh fraction ,single stage/single pas

Run	Feedrate	Feed		Mag.			N. Mag.			Recovery			
										Mag.		N.Mag.	
	tph	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	kcl	W.I.	kcl	W.I.
41	7.7	33.2	8.8	9.2	26.9	33.6	90.8	33.9	6.3	7.5	35.2	92.5	64.8
42	8.7	32.3	9.2	11.5	24.4	37.2	88.5	33.3	5.6	8.7	46.4	91.3	53.6
44	9.6	30.4	10.6	5.3	21.6	44.8	94.7	30.9	8.7	3.8	22.4	96.2	77.6
43	9.0	31.6	10.8	18.8	26.9	28.6	81.2	32.6	6.7	16.0	49.9	84.0	50.1
45	9.1	30.4	11.2	24.6	25.1	27.2	75.4	32.1	6.0	20.3	59.9	79.7	40.1
53	11.2	33.0	6.1	3.1	21.4	42.1	96.9	33.4	4.9	2.0	21.6	98.0	78.4
52	11.4	33.6	6.0	6.7	27.6	27.1	93.3	34.0	4.5	5.5	30.2	94.5	69.8
46	11.7	34.7	5.6	7.6	37.3	17.1	92.4	34.5	4.7	8.2	23.0	91.8	77.0
51	11.0	33.4	5.5	10.9	29.7	20.5	89.1	33.9	3.7	9.7	40.4	90.3	59.6
54	12.8	31.9	5.9	2.6	19.4	49.4	97.4	32.2	4.7	1.6	21.9	98.4	78.1
48	13.1	33.8	7.9	4.9	23.3	40.1	95.1	34.3	6.2	3.4	25.0	96.6	75.0
47	13.8	33.1	7.5	13.6	29.0	21.4	86.4	33.8	5.3	11.9	38.9	88.1	61.1
49	13.4	29.5	8.1	21.3	28.4	20.7	78.7	29.8	4.7	20.5	54.4	79.5	45.6

Table 3. Summary of test results - CCP 6x28 mesh fraction at various feed rate

Table 3.1 Single stage/sigle pass at 2.7 tph

Run	Feed		Mag.			N. Mag.			Recovery			
									Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	kcl	W.I.	kcl	W.I.
10	40.8	3.9	4.3	23.6	42.6	95.7	41.6	2.2	2.5	46.8	97.5	53.2
13	39.3	4.1	5.3	27.9	34.8	94.7	40.0	2.4	3.8	44.7	96.2	55.3
11	40.9	3.2	5.9	32.1	28.4	94.1	41.5	1.7	4.6	51.9	95.4	48.1
16	40.1	4.5	7.8	30.4	30.0	92.2	40.9	2.4	5.9	51.6	94.1	48.4
15	40.7	3.8	9.1	33.8	24.7	90.9	41.4	1.8	7.6	58.4	92.4	41.6
14	38.8	4.9	12.2	33.0	26.0	87.8	39.6	2.0	10.4	64.1	89.6	35.9
12	40.1	4.2	17.1	38.0	16.6	82.9	40.6	1.7	16.2	67.1	83.8	32.9
17	39.2	4.3	18.8	38.2	15.3	81.2	39.4	1.8	18.3	66.4	81.7	33.6

Table 3.2 Single/single pass at 4.4 tph

Run	Feed		Mag.			N. Mag.			Recovery			
									Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
19	39.0	4.5	2.4	16.9	53.7	97.6	39.6	3.3	1.0	28.6	99.0	71.4
22	38.5	5.0	2.9	18.8	50.1	97.1	39.1	3.7	1.4	29.1	98.6	70.9
23	39.2	4.2	4.8	27.3	35.3	95.2	39.8	2.6	3.3	40.8	96.7	59.2
18	39.2	4.7	4.9	23.6	40.5	95.1	40.0	2.9	3.0	42.3	97.0	57.7
20	39.1	4.9	8.3	28.3	32.3	91.7	40.1	2.4	6.0	55.0	94.0	45.0
24.1	38.7	4.8	12.5	37.0	18.0	87.5	39.0	3.0	11.9	46.3	88.1	53.7
21	37.1	5.3	17.8	34.8	19.9	82.2	37.6	2.2	16.7	66.3	83.3	33.7
24.2	39.1	4.7	33.3	39.5	10.1	66.7	38.9	2.0	33.7	71.5	66.3	28.5

Table 3.3 Single stage/single pass at 6.2 tph

Run	Feed		Mag.			N. Mag.			Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	kcl	W.I.	kcl	W.I.
28	34.7	1.9	1.6	24.6	25.0	98.4	34.9	1.6	1.1	20.6	98.9	79.4
29	34.6	2.2	2.4	29.0	18.8	97.6	34.7	1.8	2.0	20.5	98.0	79.5
25	38.3	4.7	2.9	23.2	41.1	97.1	38.8	3.6	1.8	25.3	98.2	74.7
30	35.0	2.1	4.6	29.5	17.2	95.4	35.3	1.4	3.9	37.6	96.1	62.4
27	36.4	1.7	11.0	37.8	6.5	89.0	36.2	1.2	11.4	41.0	88.6	59.0

Table 3. Summary of test results - CCP 6x28 mesh fraction ay various feed rate

Table 3.4 Single stage/single pass 8.2 tph

Run	Feedrate tph	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	% Recoverry Mag. kcl	% Recoverry Mag. W.I.	% Recoverry N.Mag. kcl	% Recoverry N.Mag. W.I.
59	8.6	38.7	6.7	2.8	25.2	39.2	97.2	39.1	5.8	1.8	16.3	98.2	83.7
58	7.6	39.3	5.1	3.2	28.5	34.4	96.8	39.6	4.1	2.3	21.6	97.7	78.4
60	8.5	37.7	6.2	9.6	36.7	18.5	90.4	37.8	4.9	9.4	28.7	90.6	71.3
57	7.9	40.5	5.8	9.9	39.2	15.6	90.1	40.7	4.7	9.6	26.6	90.4	73.4
61	8.6	36.9	7.0	14.0	36.7	17.2	86.0	36.9	5.4	13.9	34.3	86.1	65.7

Table 3.5 Single stage/single pass at 8 to 13 tph

Run	Feedrate tph	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
37	9.2	33.6	6.2	3.1	24.0	38.0	96.9	33.9	5.2	2.2	19.0	97.8	81.0
38	9.3	31.9	6.9	3.7	25.6	33.9	96.3	32.1	5.9	3.0	18.1	97.0	81.9
39	9.2	31.0	7.3	5.6	23.6	36.3	94.4	31.4	5.6	4.3	27.8	95.7	72.2
32	8.1	23.3	3.9	8.0	23.4	13.4	92.0	23.3	3.1	8.0	27.3	92.0	72.7
34	12.6	31.1	4.0	2.9	23.3	23.3	97.1	31.4	3.4	2.2	17.0	97.8	83.0
35	12.7	30.2	4.1	7.5	27.8	14.7	92.5	30.4	3.3	6.9	26.8	93.1	73.2

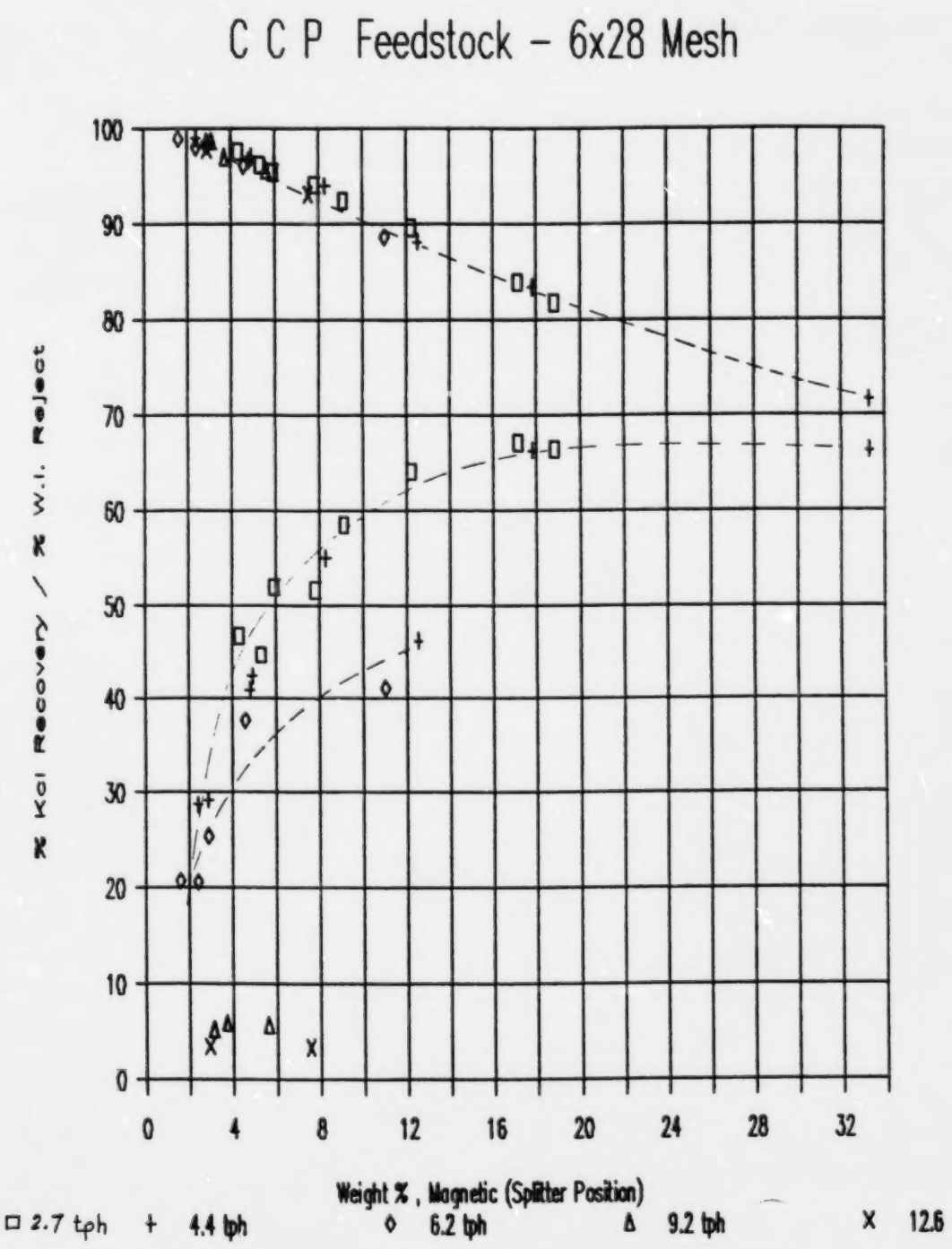

Figure 11. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - CCP feedstock - 6 x 28 mesh

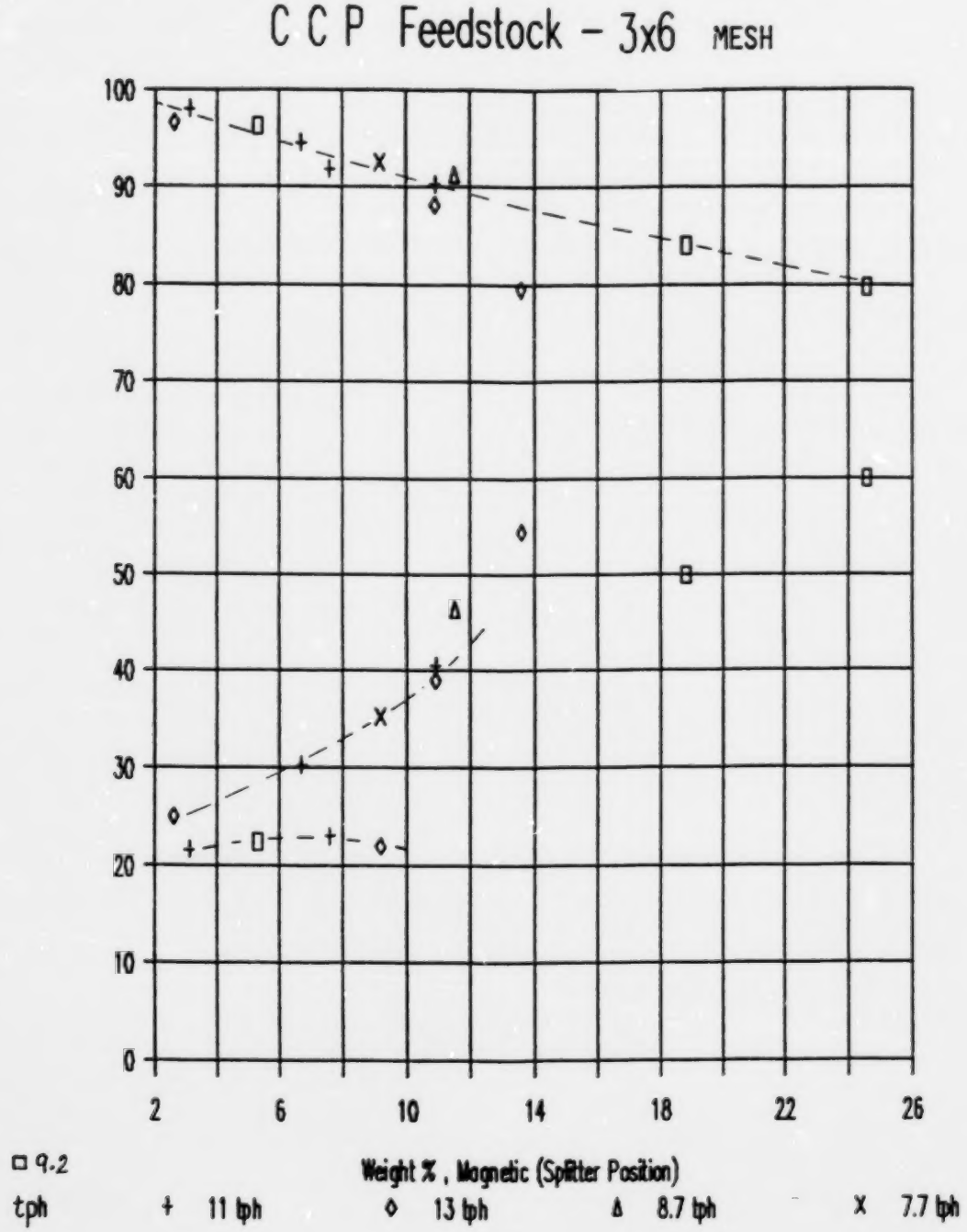

Figure 12. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - CCP feedstock - 3 x 6 mesh

3.0.2 Results and Discussion - PCS Lanigan Division High Clay Ore

Test results of the Lanigan Division high clay ore are summarized in Tables 4, 5 and 6 for 7/16" x 3 mesh, 3 x 6 mesh and 6 x 28 mesh fractions respectively. The relationship between the % KCl recovery and % WI rejection of the 7/16" x 3 mesh, 3 x 6 mesh and 6 x 28 mesh fractions at a 5 tph and 9 tph feed rate with first pass and second pass is shown in Figures 13, 14 and 15 respectively. For the 7/16" x 3 mesh fraction (Figure 13), the % KCl recovery decreased gradually with the weight % (splitter position), while the % WI rejection in the magnetic increased and flattened out at about 24%. About 90% KCl recovery and 45% WI rejection could be obtained at a 20-21% weight split. For the 3 x 6 mesh fraction (Figure 14), the % WI rejection increased and flattened out at about a 15.5% weight split. About 92% KCl recovery and 45% WI rejection appeared at a 15% weight split. For the 6 x 28 mesh fraction (Figure 15), the feed rate effect was apparent for WI rejection, but was not so distinct for the KCl recovery. It appears that results (% KCl recovery and % WI rejection) of the first pass and second pass for the same size fraction and feed rate, particularly at low feed rate, followed the same correlation. The second pass results of run 143 (Table 5.5) for example, upgraded KCl from 22.6% to 25% (about 10%) and reduced WI from 12.0% to 7.6% (about 36%) at 93.5% KCl recovery in non-magnetic stream and 46.6% WI (clay) rejection in magnetic respectively.

Table 4. Summary of test results - PCS Lanigan devision high clay ore - 7/16"x3 mesh fraction at various feed rate

Table 4.1 Single stage/single pass, 5 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
100	14.2	18.1	3.6	4.2	53.1	96.4	14.6	16.8	1.1	10.6	98.9	89.4
97	18.0	18.8	4.4	4.4	54.5	95.6	18.6	17.2	1.1	12.7	98.9	87.3
98	13.6	18.3	9.2	2.8	49.4	90.8	14.7	15.2	1.9	24.8	98.1	75.2
99	17.9	19.7	19.0	5.6	41.7	81.0	20.8	14.6	5.9	40.1	94.1	59.9
101	17.2	20.8	26.7	6.8	36.3	73.3	21.0	15.1	10.6	46.7	89.4	53.3

Table 4.2 Single stage/single pass, 9.4 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
145	16.8	20.0	2.2	15.0	33.2	97.8	16.9	19.7	1.9	3.6	98.1	96.4
144	16.6	16.5	6.6	24.0	21.2	93.4	16.1	16.2	9.5	8.4	90.5	91.6
146	15.2	17.1	9.1	6.7	42.4	90.9	16.1	14.5	4.0	22.6	96.0	77.4

Table 4.3 Single stage/single pass, 8.9 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
147	14.1	14.0	1.1	11.4	41.8	98.9	14.2	13.7	0.9	3.3	99.1	96.7
148	17.1	17.7	4.3	6.5	48.5	95.7	17.6	16.3	1.7	11.9	98.3	88.1
149	21.4	15.2	21.1	11.7	33.4	78.9	24.0	10.4	11.5	46.2	88.5	53.8
150	19.0	18.0	9.4	9.5	37.2	90.6	20.0	16.0	4.7	19.4	95.3	80.6

Table 4. Summary of test results - PCS Lanigan devision high clay ore

Table 4.4 Single stage/single pass, 5.0 tph

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
102	16.5	19.8	2.9	7.0	44.9	97.1	16.8	19.0	1.2	6.6	98.8	93.4
104	15.9	14.5	4.6	5.3	49.1	95.4	16.4	12.8	1.5	15.7	98.5	84.3
103	15.0	17.7	9.3	4.2	46.3	90.7	16.1	14.8	2.6	24.2	97.4	75.8
105	15.2	15.9	19.7	10.4	36.1	80.3	16.4	10.9	13.4	44.8	86.6	55.2

Table 4.5 Single stage/single pass at 2.2 tph using magnetic stream of run 146 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
158	8.4	40.4	38.3	6.9	51.4	61.7	9.4	33.5	31.3	48.8	68.7	51.2
159	4.9	42.8	64.0	4.5	48.9	36.0	5.7	32.0	58.4	73.1	41.6	26.9
160	6.4	47.0	89.3	5.6	49.6	10.7	13.3	25.0	77.9	94.3	22.1	5.7

Table 4.6 Single stage/single pass at 1.7 tph using magnetic stream of run 101 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
125	8.9	32.9	32.6	5.0	48.9	67.4	10.8	25.1	18.3	48.5	81.7	51.5
126	8.2	36.2	72.2	5.3	42.2	27.8	15.7	20.5	46.7	84.2	53.3	15.8
127	9.9	33.2	52.1	6.0	46.2	47.9	14.1	19.1	31.6	72.4	68.4	27.6

Table 5. Summary of test results - PCS Lanigan devision High clay ore - 3x6 mesh fraction at various feed rate

Table 5.1 Single stage/single pass, 0.9 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
122	6.1	49.3	74.8	5.8	54.1	25.2	7.0	34.9	71.0	82.2	29.0	17.8
123	6.1	48.5	54.8	5.2	57.0	45.2	7.1	38.1	47.4	64.4	52.6	35.6
124	7.1	49.1	29.9	5.6	59.7	70.1	7.7	44.5	23.6	36.4	76.4	63.6

Table 5.2 Single stage/single pass, 5 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
117	20.5	16.2	6.6	4.5	56.8	93.4	21.7	13.4	1.4	23.0	98.6	77.0
115	21.7	16.8	6.6	5.5	57.0	93.4	22.9	13.9	1.7	22.6	98.3	77.4
114	21.6	16.0	9.0	5.6	55.4	91.0	23.2	12.1	2.3	31.3	97.7	68.7
116	19.9	17.3	14.0	5.2	54.1	86.0	22.3	11.3	3.7	43.8	96.3	56.2
118	22.3	16.4	15.9	6.3	50.4	84.1	25.3	10.0	4.5	48.9	95.5	51.1

Table 5.3 Single stage/second pass at 5 tph using the non-magnetic stream of run 117 as feedstock

Run	Feed		Mag.			N. Mag.			RECOVERY			
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
119	19.3	14.9	4.2	6.5	52.4	95.8	19.8	13.3	1.4	14.6	98.6	85.4
120	23.2	13.8	7.8	4.7	50.5	92.2	24.8	10.7	1.6	28.5	98.4	71.5
121	22.5	13.2	15.1	6.0	44.7	84.9	25.5	7.6	4.0	51.3	96.0	48.7

Table 5. Summary of test results - PCS Lanigan devision High clay ore - 3x6 mesh fraction at various feed rate

Table 5.4 Single stage/single pass, 9 tph

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
138	20.1	15.0	8.9	6.6	50.6	91.1	21.4	11.5	2.9	29.9	97.1	70.1
139	21.8	16.6	5.2	6.4	53.5	94.8	22.7	14.5	1.5	16.7	98.5	83.3
140	22.2	16.5	17.8	9.8	37.7	82.2	24.9	11.9	7.9	40.6	92.1	59.4
141	21.1	14.8	4.2	7.5	49.7	95.8	21.7	13.3	1.5	14.0	98.5	86.0
142	23.8	13.2	7.8	8.7	43.1	92.2	25.1	10.7	2.8	25.3	97.2	74.7

Table 5.5 Single stage/second pass at 10 tph using the non-magnetic stream of run 139 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
141	21.1	14.8	4.2	7.5	49.7	95.8	21.7	13.3	1.5	14.0	98.5	86.0
142	23.8	13.2	7.8	8.7	43.1	92.2	25.1	10.7	2.8	25.3	97.2	74.7
143	22.6	12.0	15.3	9.6	36.5	84.7	25.0	7.6	6.5	46.6	93.5	53.4

Table 5.6 Single stage/second pass at 10 tph using the non-magnetic stream of run 140 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
156	10.7	37.2	33.1	5.4	56.6	66.9	13.3	27.6	16.7	50.3	83.3	49.7
155	10.7	36.4	50.7	6.0	53.8	49.3	15.5	18.5	28.4	75.0	71.6	25.0
154	12.0	35.0	62.2	7.9	47.2	37.8	18.8	14.9	40.8	83.9	59.2	16.1
157	10.6	38.2	83.4	8.5	44.2	16.6	21.2	8.3	66.8	96.4	33.2	3.6

Table 6. Summary of test results - PCS Lanigan devision high clay ore - 6x26 mesh fraction at various feed rate

Table 6.1 Single stage/single pass,5 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
									Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
109	29.9	12.3	6.5	10.0	51.8	93.5	31.3	9.5	2.2	27.6	97.8	72.4
107	31.4	10.6	6.8	11.3	50.9	93.2	32.8	7.7	2.4	32.3	97.6	67.7
106	31.5	10.6	10.8	17.0	39.1	89.2	33.3	7.2	5.8	39.7	94.2	60.3
108	32.0	10.8	16.8	21.1	31.5	83.2	34.2	6.7	11.1	48.9	88.9	51.1
110	31.4	10.8	18.1	21.7	29.9	81.9	33.5	6.6	12.5	50.0	87.5	50.0

Table 6.2 Single stage/single pass,9.1 tph

Run	Feed		Mag.			N. Mag.			RECOVERY			
									Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
132	30.2	12.5	4.7	13.0	45.7	95.3	31.1	10.8	2.0	17.4	98.0	82.6
131	30.6	11.6	11.8	20.6	30.8	88.2	32.0	9.1	8.0	31.3	92.0	68.7
133	32.2	10.3	22.6	28.0	18.2	77.4	33.4	8.0	19.7	39.8	80.3	60.2

Table 6.3 Single stage/second at 5 tph using non-magnetic stream of run 109

Run	Feed		Mag.			N. Mag.			RECOVERY			
									Mag.		N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
111	32.4	8.4	3.7	10.3	49.4	96.3	33.2	6.8	1.2	21.7	98.8	78.3
112	32.5	8.2	5.3	12.9	42.7	94.7	33.6	6.3	2.1	27.6	97.9	72.4
113	32.0	8.9	12.9	21.5	28.3	87.1	33.5	6.1	8.6	40.7	91.4	59.3

Table 6. Summary of test results - PCS Lanigan devision high clay ore - 6x26 mesh fraction at various feed rate

Table 6.4 Single stage/second at 8.9 tph using non-magnetic stream of run 132

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
135	32.9	9.3	3.7	11.4	48.2	96.3	33.7	7.8	1.3	19.0	98.7	81.0
134	33.3	9.3	5.4	16.7	37.6	94.6	34.2	7.7	2.7	21.8	97.3	78.2
137	31.6	9.4	9.7	20.46	29.84	90.3	32.98	7.26	6.2	30.6	93.8	69.4
136	33.3	8.5	15.8	27.4	19.0	84.2	34.4	6.5	13.0	35.3	87.0	64.7

Table 6.5 Single stage/second pass at 1.1 tph using magnetic stream of run 133 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
153	27.1	19.8	33.1	13.8	44.2	66.9	33.7	7.7	16.8	73.9	83.2	26.1
152	25.7	21.8	49.4	16.8	37.6	50.6	34.4	6.4	32.2	85.2	67.8	14.8
151	26.9	20.7	72.5	24.1	26.62	27.5	34.24	5.23	65.0	93.1	35.0	6.9

Table 6.6 Single stage/second pass at 5 tph using magnetic stream of run 110 as feedstock

Run	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
130	20.5	31.2	35.5	10.0	53.0	64.5	26.3	19.1	17.3	60.5	82.7	39.5
129	20.3	31.4	54.1	13.6	45.6	45.9	28.4	14.6	36.1	78.7	63.9	21.3
128	21.1	30.7	62.9	15.1	42.7	37.1	31.1	10.4	45.3	87.5	54.7	12.5

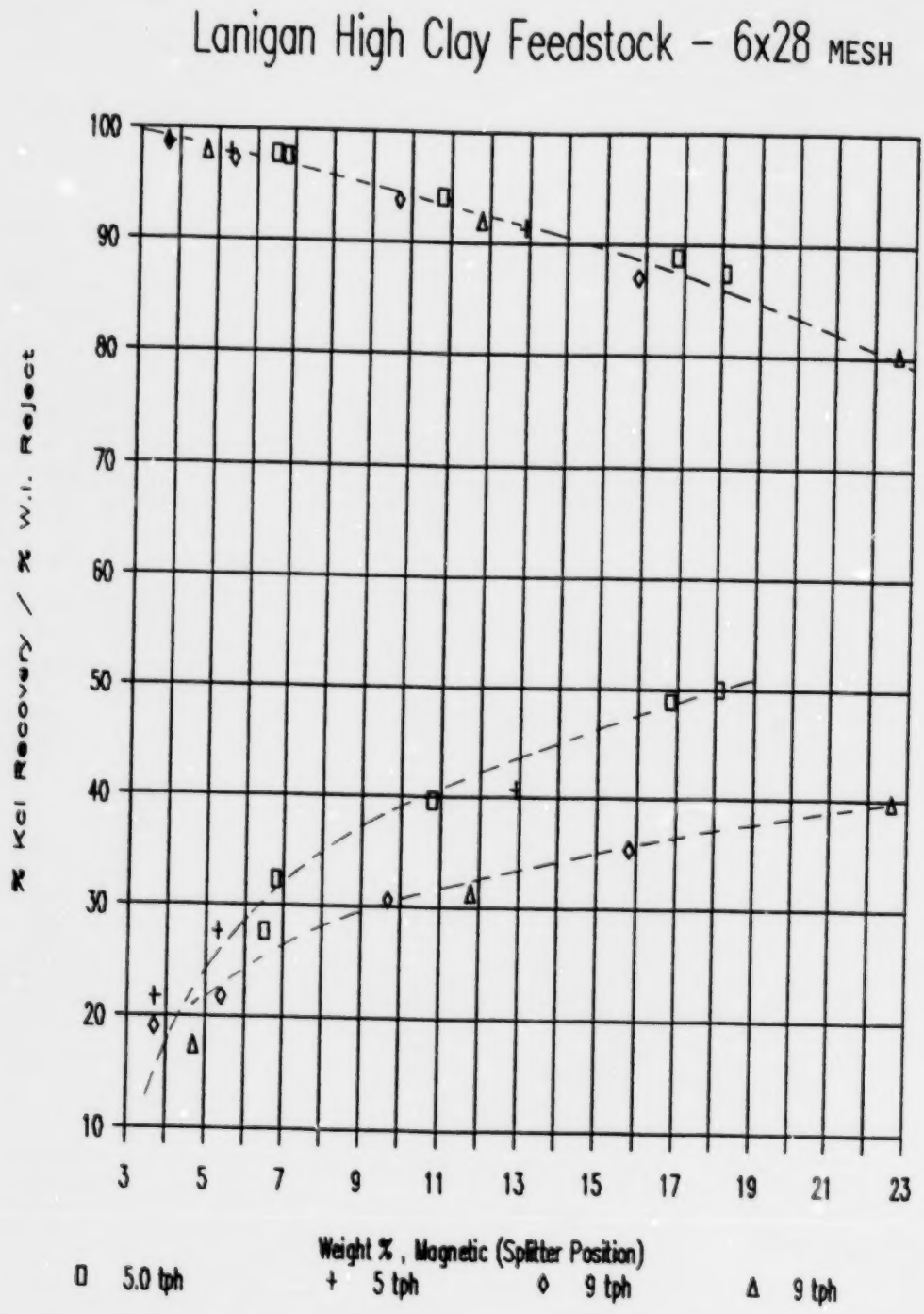

Figure 13. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division high clay feedstock - 6 x 28 mesh

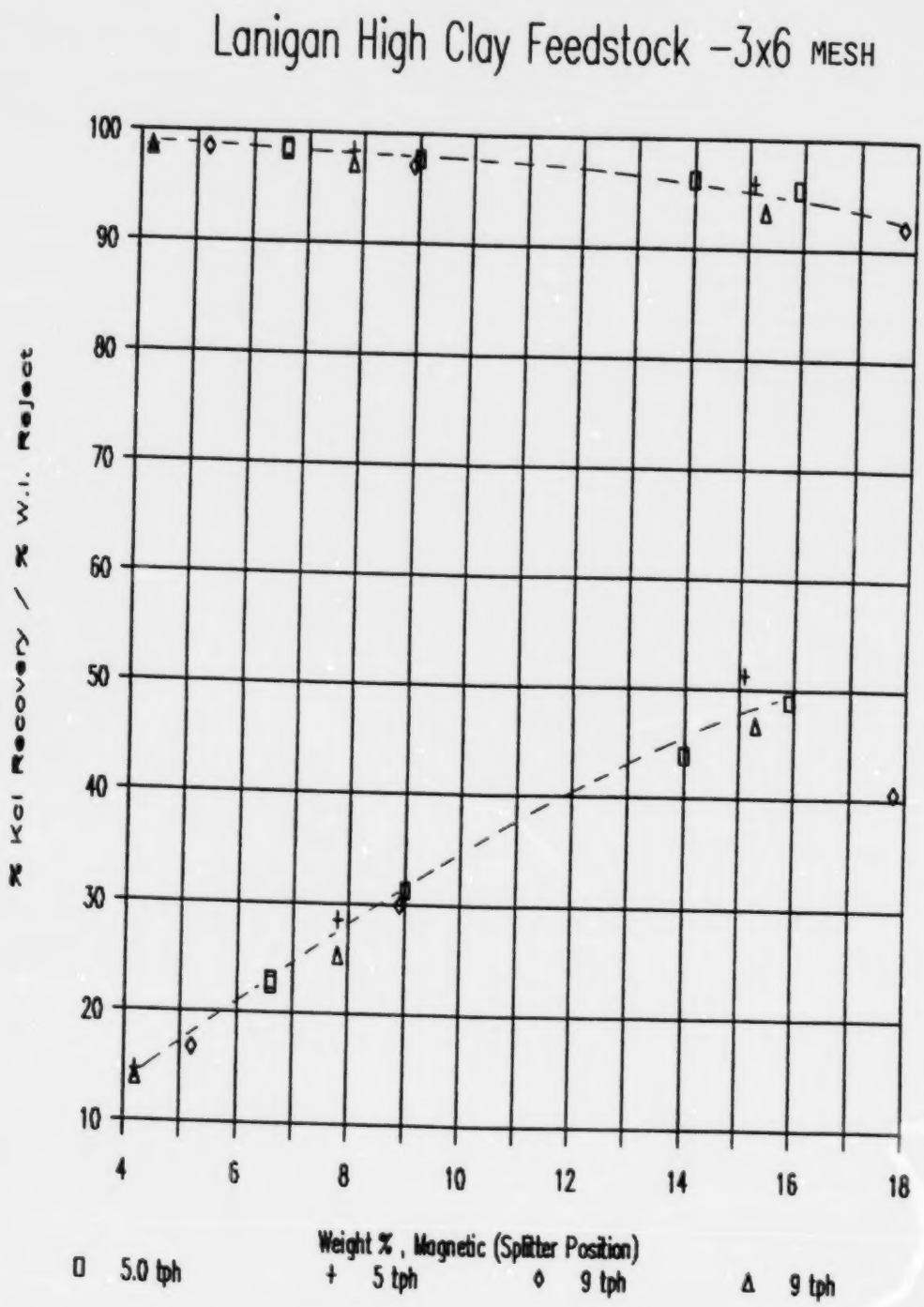

Figure 14. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division high clay feedstock - 3 x 6 mesh

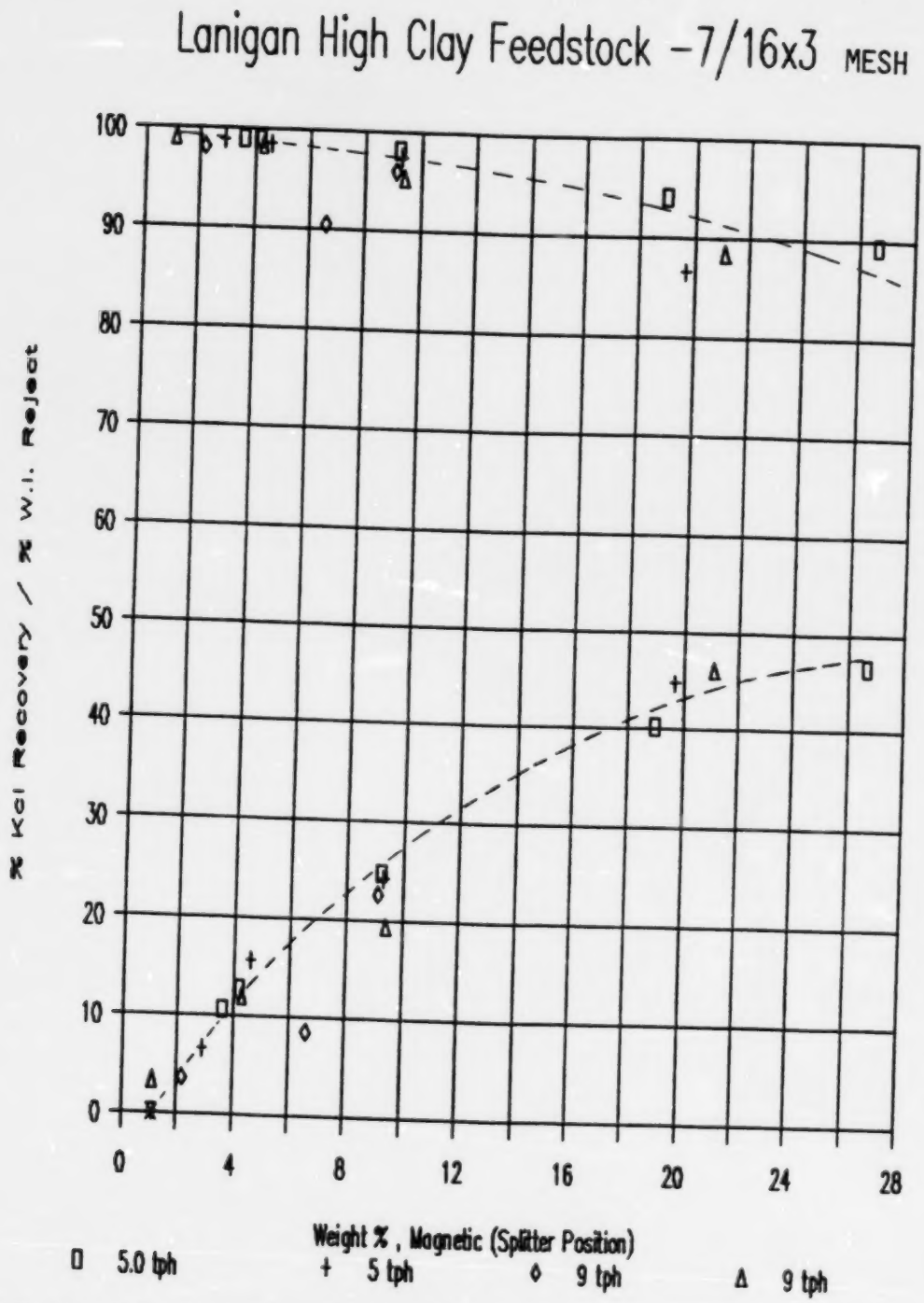

Figure 15. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division high clay feedstock - 7/16" x 3 mesh

3.0.3 Results and Discussion - PCS Lanigan Division Low Clay Ore

Test results of the Lanigan Division low clay ore are summarized in Tables 7, 8 and 9 for 7/16" x 3 mesh, 3 x 6 mesh and 6 x 28 mesh fractions respectively. The relationship between the % KCl recovery and % WI rejection of the 7/16" x 3 mesh, 3 x 6 mesh and 6 x 28 mesh fractions with weight %, magnetic (splitter position) are shown in Figures 16, 17 and 18 respectively. For the 7/16" x 3 mesh fraction (Figure 16) at the 9 to 10 tph feed rate shown, about 30% WI rejection and 90% KCl recovery was obtained at about 13% magnetic split. For the 3 x 6 mesh fraction, the WI rejection flattened out at 13-14% magnetic split. The best performance appeared to be about 45% WI rejection and about 88% KCl recovery. For the 6 x 28 fraction, 60% WI rejection and 90% KCl recovery could be obtained at 13% magnetic split. As the feed rate increased to 6 to 8 tph, the WI rejection reduced to about 30% at 90% KCl recovery. Figure 16 shows clearly how the feed rate affects the KCl rejection and WI recovery.

Table 7. Summary of test results -PCS Lanigan devision low clay ore - 7/16"x3 me
at various feed rate (single stage/single pass)

Run	Feedrate tph	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	RECOVERY Mag. %kcl	RECOVERY Mag. %W.I.	RECOVERY N.Mag. kcl	RECOVERY N.Mag. W.I.
73	9.3	26.6	10.9	1.3	20.0	41.5	98.7	26.7	10.5	1.0	5.1	99.0	94.9
77	10.5	27.6	10.0	2.1	14.1	43.1	97.9	27.9	9.3	1.1	9.2	98.9	90.8
76	10.4	27.2	10.3	8.6	18.0	30.8	91.4	28.0	8.4	5.7	25.5	94.3	74.5
75	9.3	22.4	10.5	9.6	22.0	24.9	90.4	22.4	8.9	9.4	22.8	90.6	77.2
					single stage second pass								
79	9.9	31.7	8.5	15.2	27.4	19.0	84.8	32.5	6.7	13.1	33.8	86.9	66.2
81	11.2	23.0	13.7	1.1	20.7	37.2	98.9	23.0	13.5	1.0	3.0	99.0	97.0
80	10.2	28.4	10.6	8.6	20.9	23.6	91.4	29.1	9.4	6.3	19.2	93.7	80.8
					single stage second pass								
90	2.1	17.7	28.2	29.1	11.7	44.7	70.9	20.2	21.5	19.2	46.1	80.8	53.9
88	1.9	20.8	27.5	48.0	14.3	40.0	52.0	26.9	15.8	33.0	70.0	67.0	30.0
89	2.0	18.2	30.7	68.8	17.1	36.9	31.2	20.7	16.8	64.4	82.9	35.6	17.1

Note: Run 79,80 and 81 used the non-magnetic of run 77 as feedstock
Run 88,89 and 90 used the magnetic of run 76 as feedstock

Table 8. Summary of test results - PCS Lanigan devision low clay ore
3x6 mesh fraction (single stage/first and second pass)

Run	Feedrate	Feed		Mag.			N. Mag.			RECOVERY			
										Mag.		N.Mag.	
		%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
45	1.2	32.8	11.5	3.4	14.9	56.8	96.6	33.4	9.9	1.5	16.7	98.5	83.3
46	1.2	32.8	10.0	12.6	19.4	34.0	87.4	34.7	6.5	7.4	42.8	92.6	57.2
30	6.4	32.2	10.6	3.1	12.6	52.7	96.9	32.8	9.3	1.2	15.4	98.8	84.6
31	6.2	32.8	10.2	6.5	16.0	45.4	93.5	33.9	7.8	3.2	28.8	96.8	71.2
66	8.1	31.4	9.3	18.4	24.8	22.9	81.6	34.6	6.4	14.5	45.3	85.5	54.7
68	10.1	33.9	7.7	2.8	16.1	41.7	97.2	31.6	8.0	1.3	15.3	98.7	84.7
65	10.1	32.6	8.8	9.0	25.5	25.1	91.0	33.3	7.2	7.0	25.7	93.0	74.3
49	1.2	32.4	7.6	3.1	15.8	43.0	96.9	32.9	6.4	1.5	17.6	98.5	82.4
38	1.1	17.3	43.1	76.0	16.1	47.4	24.0	21.1	29.4	70.6	83.6	29.4	16.4
50	1.2	36.8	6.6	6.5	18.0	34.5	93.5	38.1	4.62	3.2	34.3	96.8	65.7
53	1.2	16.8	37.9	83.5	15.2	41.9	16.5	25.1	17.6	75.5	92.4	24.5	7.6
54	1.1	18.4	38.4	30.1	12.5	56.9	69.9	20.9	30.5	20.5	44.6	79.5	55.4
35	6.3	32.6	8.2	6.0	16.4	39.1	94.0	33.6	6.2	3.0	28.7	97.0	71.3

Note: run 49 and 50 used the non-magnetic of run 45 as feedstock
run 35 used the non-magnetic of run 30 as feedstock
run 38 used the magnetic of run 31 as feedstock
run 53 used the magnetic of run 46 as feedstock

Table 9. Summary of test results - PCS Lanigan devision low clay ore
6x28 mesh fraction at various feed rate (single stage/first and second pass)

Run	Feedrate	Feed		Mag.			N. Mag.			RECOVERY			
		%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	Mag. %kcl	Mag. %W.I.	N.Mag. kcl	N.Mag. W.I.
1	1.2	43.5	6.3	6.5	23.0	46.5	93.5	45.0	3.5	3.4	47.9	96.6	52.1
3	1.2	40.8	7.1	12.9	30.3	33.5	87.1	42.3	3.2	9.6	60.6	90.4	39.4
6	1.2	44.2	3.3	3.7	29.1	30.9	96.3	44.8	2.2	2.4	34.7	97.6	65.3
8	1.3	44.0	4.0	16.1	40.1	15.9	83.9	44.8	1.7	14.7	64.2	85.3	35.8
11	1.4	31.4	31.7	81.8	30.2	35.2	18.2	36.7	16.1	78.7	90.8	21.3	9.2
12	1.3	32.5	30.8	39.6	24.9	45.9	60.4	37.4	20.9	30.4	59.0	69.6	41.0
13	6.6	40.8	6.2	23.1	39.0	14.0	76.9	41.4	3.9	22.0	52.2	78.0	47.8
15	5.8	40.7	8.2	4.5	23.2	42.8	95.5	41.5	6.5	2.6	23.6	97.4	76.4
18	6.7	40.9	7.5	9.5	33.7	25.4	90.5	41.7	5.6	7.8	32.0	92.2	68.0
20	6.0	36.1	22.5	39.8	34.5	28.2	60.2	37.1	18.8	38.1	49.7	61.9	50.3
21	6.5	34.2	25.0	64.4	34.6	26.5	35.6	33.6	22.3	65.1	68.2	34.9	31.8
23	6.2	41.5	6.8	14.3	36.5	18.4	85.7	42.3	4.9	12.6	38.5	87.4	61.5
24	6.3	41.5	6.2	3.5	24.0	38.2	96.5	42.1	5.0	2.0	21.7	98.0	78.3
55	8.9	44.3	5.5	10.4	38.3	17.3	89.6	45.0	4.1	9.0	32.7	91.0	67.3
57	9.3	36.5	10.2	14.5	36.3	18.2	85.5	36.6	8.9	14.4	25.9	85.6	74.1
60	10.8	40.5	6.8	2.5	27.9	37.7	97.5	40.8	6.0	1.8	14.1	98.2	85.9
61	9.9	41.3	6.0	2.4	30.5	32.5	97.6	41.6	5.3	1.8	13.2	98.2	86.8
62	10.6	43.9	4.8	6.4	37.4	17.7	93.6	44.3	4.0	5.5	23.6	94.5	76.4
63	10.8	41.5	5.3	8.2	39.3	15.3	91.8	41.7	4.4	7.7	23.6	92.3	76.4

Note : run 20and 21 used the magnetic of run 18 as feedstock

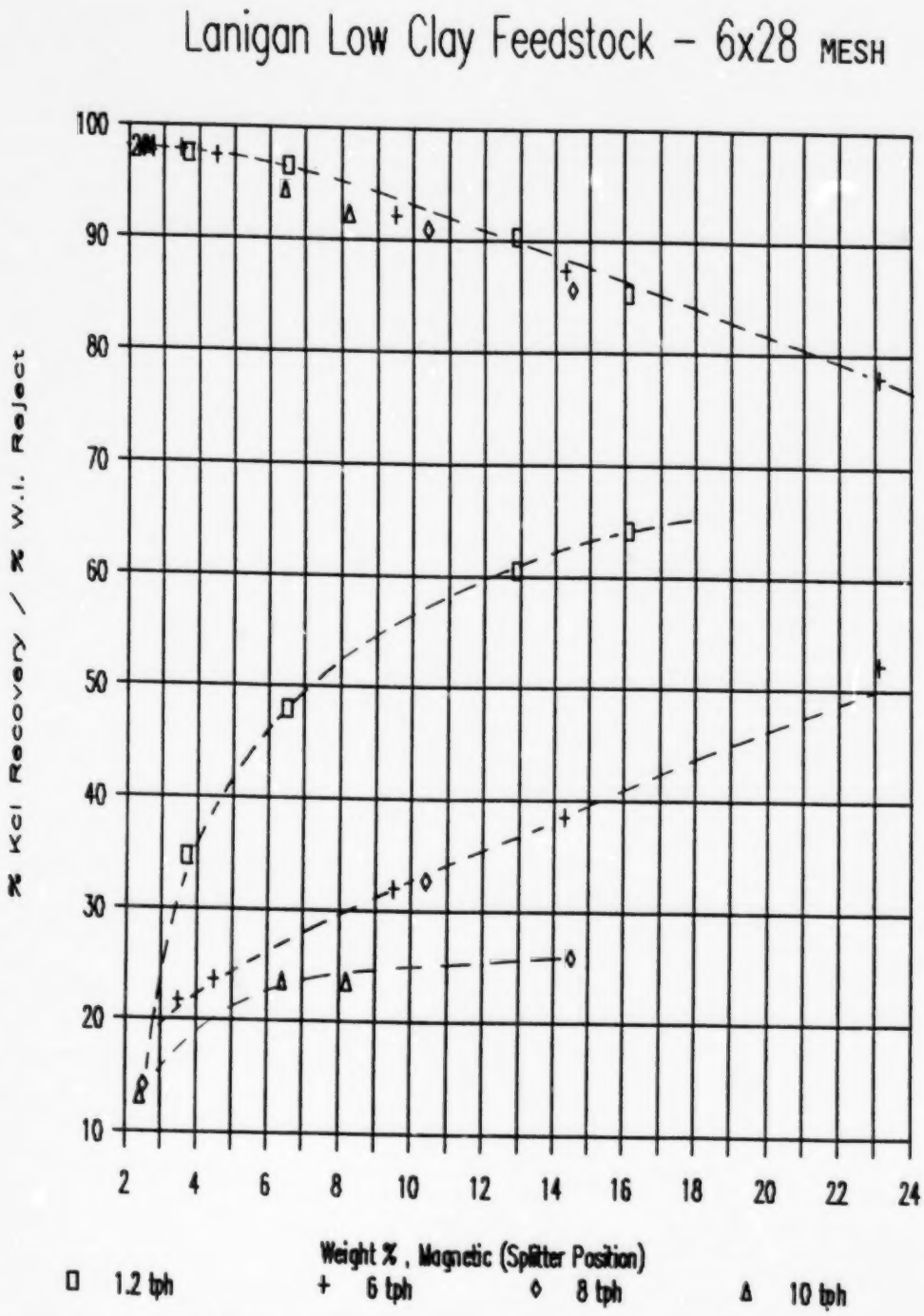

Figure 16. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division low clay feedstock - 6 x 28 mesh

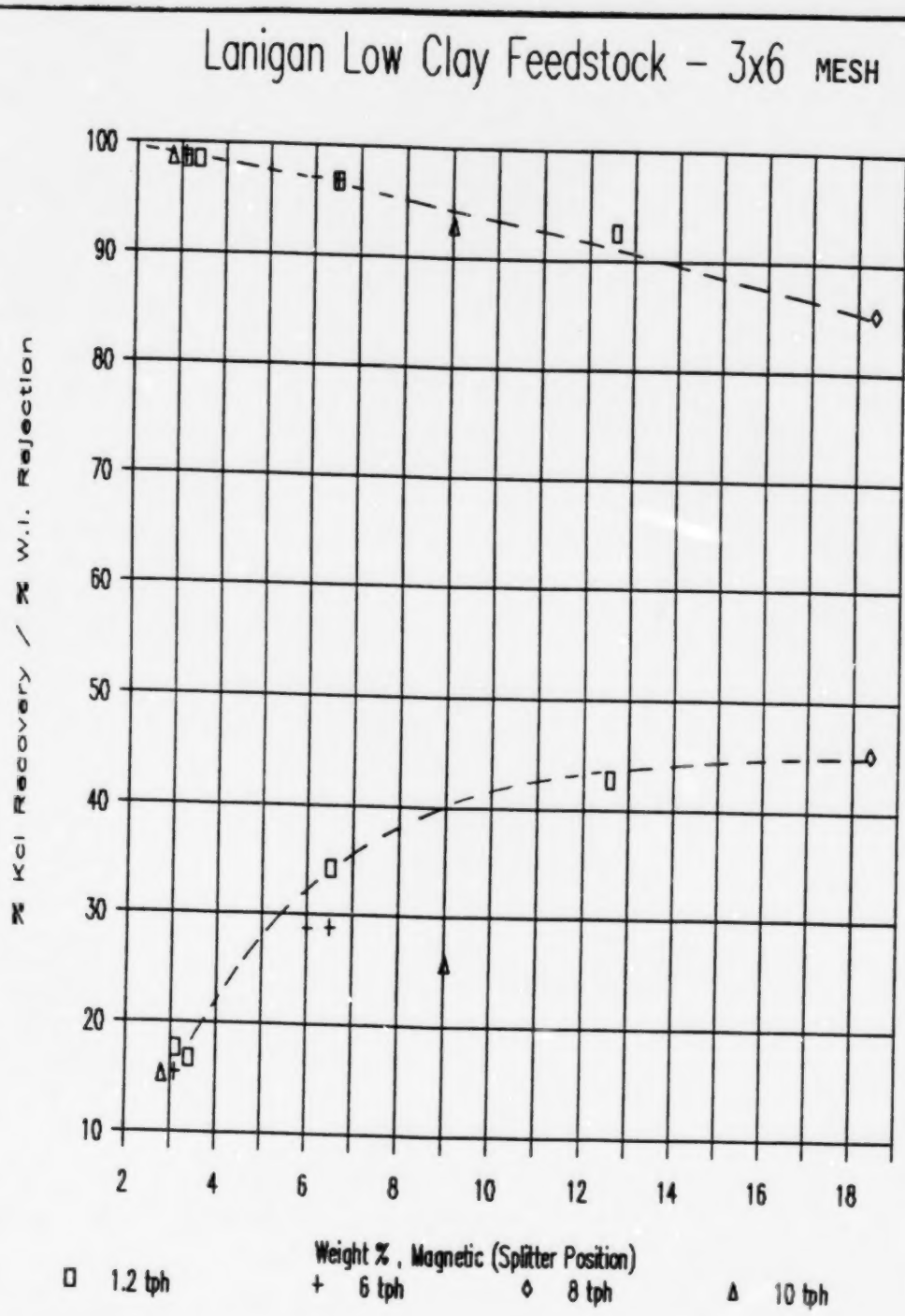

Figure 17. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division low clay feedstock - 3 x 6 mesh

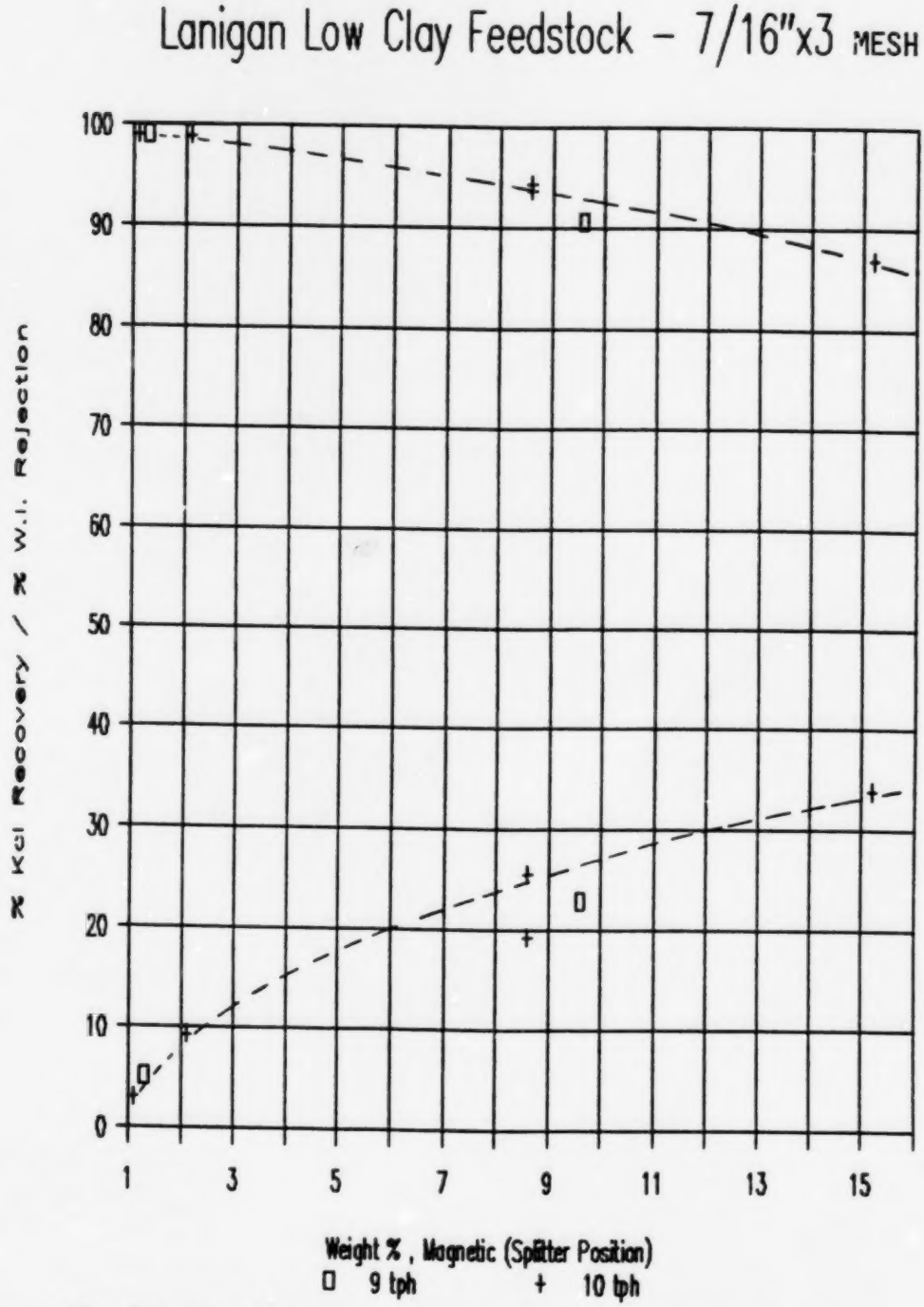

Figure 18. Relationship between % KCl recovery in non-magnetic, the % WI rejection in magnetic at various feed rates, and weight % magnetic (splitter gate position) - PCS Lanigan Division low clay feedstock - 7/16" x 3 mesh

3.0.4 Other Feedstock

Three additional sets of tests with size fractions of 1" x 3 mesh, 10 x 20 mesh and +28 mesh fractions were carried out and results are summarized in Tables 10, 11 and 12 respectively. Figure 19 shows the correlation between % KCl recovery and WI rejection of the 1" x 3 mesh, 10 x 20 mesh and +28 mesh fractions with respect to weight % magnetic (splitter position). The 1" x 3 mesh fraction, the coarsest fraction tested so far, showed very poor WI rejection in the magnetic and grade (%KCl) in the non-magnetic. The poor performance of the 1" x 3 mesh fraction was perhaps due to insufficient clay liberation and too coarse a particle size which could not be pulled out by the magnetic field not designed for such big particle sizes.

The +28 mesh fraction was prepared by screening off the -28 mesh fraction from a Lanigan mill feed sample. The test was done at 8 tph and the result showed poor WI rejection in the magnetic. As the feedstock has a wide particle size distribution up to 1", segregation occurred immediately on the vibratory pan feeder and on the belt with finer particle sizes distributed closer to the Permroll roll. Visual observation showed that only finer clay particles were collected in the magnetic.

The 10 x 20 mesh fraction was tested to confirm the particle size effect - the narrower the particle size fraction, the better the separator performed. Results (Figure 19) showed that about 30% WI rejection could be obtained at 10 tph feed rate and seemed slightly better than that of the 6 x 28 mesh fraction under similar test conditions.

Table 10. Summary of test results - PCS Lanigan devision high clay ore -1"x3 mesh fraction at 5 tph (single/single pass)

Run	Feed		Mag.			N. Mag.			RECOVERY Mag.		RECOVERY N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
211	17.3	30.3	2.8	10.3	41.5	97.2	17.5	30.0	1.7	3.9	98.3	96.1
212	12.7	23.8	3.4	8.8	46.1	96.6	12.9	23.0	2.3	6.5	97.7	93.5
213	12.8	22.4	4.9	10.4	39.4	95.1	12.9	21.5	4.0	8.7	96.0	91.3
214	13.7	28.1	7.9	11.8	34.1	92.1	13.8	27.6	6.9	9.6	93.1	90.4

Table 11. Results of PCS Lanigan Devision Low clay ore - 10x20 Mesh fraction at 10 tph (single stage/single pass)

Run	Feed		Mag.			N. Mag.			RECOVERY Mag.		RECOVERY N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
191	44.3	4.3	3.2	29.3	28.8	96.8	44.8	3.5	2.1	21.4	97.9	78.6
192	44.2	4.9	8.9	37.5	16.4	91.1	44.8	3.7	7.6	30.0	92.4	70.0
193	43.5	5.0	3.5	27.0	32.2	96.5	44.1	4.1	2.2	22.1	97.8	77.9
194	44.0	3.8	2.6	27.5	31.6	97.4	44.5	3.0	1.6	22.0	98.4	78.0
195	44.0	3.7	5.3	36.8	18.0	94.7	44.4	2.9	4.5	26.1	95.5	73.9
196	43.2	4.3	15.2	41.3	9.9	84.8	43.6	3.3	14.5	34.8	85.5	65.2

Table 12. Summary of test results - PCS Lanigan devision +28 mesh mill feed at 8 tph (single stage/single pass)

Run	Feed		Mag.			N. Mag.			RECOVERY Mag.		RECOVERY N.Mag.	
	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%Wt.	%kcl	%W.I.	%kcl	%W.I.	kcl	W.I.
215	36.2	10.8	2.5	26.3	39.4	97.5	36.4	10.1	1.8	9.2	98.2	90.8
216	38.2	5.5	1.5	27.1	36.8	98.5	38.4	5.0	1.1	10.1	98.9	89.9
217	24.9	6.7	2.2	35.7	20.5	97.8	24.7	6.4	3.2	6.9	96.8	93.1

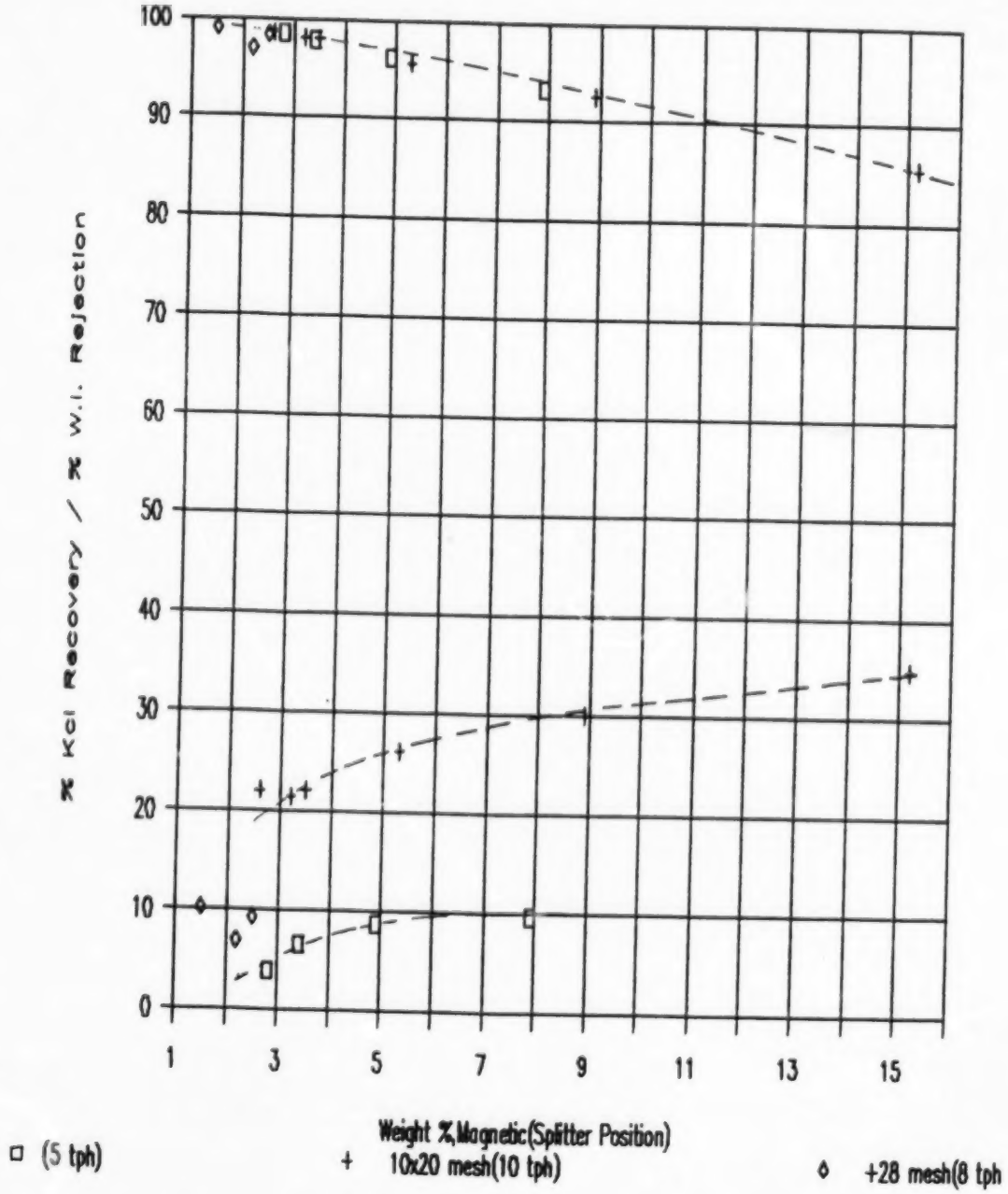

Figure 19. Relationship between % KCl recovery in non-magnetic, % WI rejection in magnetic and weight % magnetic (splitter gate position) with 1"x3 mesh, 10x20 mesh and +28 mesh fractions

3.0.5 Effect of Particle Layers (Feed Rate) on KCl Recovery and WI Rejection

The manufacturer mentions in its operation manual that thicker layers of material on the belt are found to impair the Permroll separation efficiency as the uppermost particles are subject to far less strong magnetic fields than are particles in contact with the belt. To investigate the particle layers' effect, a set of tests was performed with Lanigan 3 x 6 mesh feedstock at 0.8 tph and 5.8 tph feed rates, and at various roll speeds (Table 13). Results are summarized in Table 14 and presented in Figures 20 and 21. Figures 20.1, 20.2, 20.3 and 20.4 were pictures taken at the same 0.9 tph but at 102, 27, 9 and 5 rpm to purposely show the ore particle layers distribution while on the edge of the belt prior to falling into the splitter blade where separation occurred. As the roll speed reduced, ore particles crowded together but still in monolayer at 9.1 rpm (Figure 19.3). Further reduction of the roll speed to 4.6 rpm generated overcrowding on the monolayer and some impairment on the separator occurred as shown in Figure 22. It appeared that the overcrowded monolayer 3 x 6 mesh fraction reduced the % WI rejection. Figures 21.1, 21.2 and 21.3 were taken at the same 5.8 tph but at 52 to 150 rpm roll speed. The monolayer (Figure 21.1) became very crowded at 100 rpm and turned into overcrowded at 52 rpm. The WI rejection of runs La-19 and La-21 (52 rpm) falling off from those of 100 and 150 rpm roll speed, suggested some kind of impaired layer effect occurring (Figure 22).

Table 13. Particle layers effect -Test conditions

Run	Feedrate tph	Roll Speed	Vibrator Setting	Feedgate Opening	Splitter Setting
La-1	0.9	102.0	60	0.5	85
La-2	0.8	102.0	60	0.5	88
La-3	0.8	102.0	60	0.5	90
La-4	0.9	27.3	60	0.5	118
La-5	0.9	27.3	60	0.5	115
La-6	0.9	27.3	60	0.5	113
La-7	0.9	9.1	60	0.5	115
La-8	0.9	9.1	60	0.5	113
La-9	0.9	9.1	60	0.5	118
La-10	0.9	4.6	60	0.5	118
La-11	0.9	4.6	60	0.5	115
La-12	0.9	4.6	60	0.5	113
La-13	5.7	100.0	80	1.5	89
La-14	5.6	100.0	80	1.5	87
La-15	5.5	100.0	80	1.5	88
La-16	5.7	150.0	80	1.5	52
La-17	5.8	150.0	80	1.5	53
La-18	5.7	150.0	80	1.5	50
La-19	6.0	52.0	80	1.5	111
La-20	6.2	52.0	80	1.5	109
La-21	5.7	52.0	80	1.5	110

Table 14. Summary test results - effect particle layers on separation
(3x6 mesh fraction, single stage/single pass)

n	Feedrate tph	Feed %kcl	Feed %W.I.	Mag. %Wt.	Mag. %kcl	Mag. %W.I.	N. Mag. %Wt.	N. Mag. %kcl	N. Mag. %W.I.	Recovery Mag. kcl	Recovery Mag. W.I.	Recovery N.Mag. kcl	Recovery N.Mag. W.I.
-1	0.9	32.4	9.9	15.2	18.6	42.4	84.8	34.9	4.1	8.7	64.9	91.3	35.1
-2	0.8	32.7	8.6	7.6	16.3	42.6	92.4	34.1	5.8	3.8	38.0	96.2	62.0
-3	0.8	31.1	10.7	6.1	14.6	50.6	93.9	32.2	8.1	2.8	28.8	97.2	71.2
-4	0.9	30.4	10.7	4.7	13.0	55.1	95.3	31.3	8.6	2.0	24.0	98.0	76.0
-5	0.9	32.4	9.4	8.6	22.3	29.6	91.4	33.3	7.4	5.9	27.4	88.3	72.6
-6	0.9	26.6	13.1	16.1	13.6	49.8	83.9	31.4	6.1	7.7	61.2	92.3	38.8
-7	0.9	31.8	9.6	8.4	22.1	31.6	91.6	32.7	7.5	5.9	27.8	94.1	72.2
-8	0.9	30.6	13.0	17.1	18.0	41.6	82.9	33.2	7.1	10.1	54.7	89.9	45.3
-9	0.9	35.6	8.8	3.4	28.4	20.3	96.6	35.9	8.4	2.7	7.8	97.3	92.2
-10	0.9	31.8	8.6	2.3	18.6	42.4	97.7	32.2	7.8	1.4	11.4	98.6	88.6
-11	0.9	32.0	7.8	6.1	22.3	29.6	93.9	32.6	6.4	4.3	23.3	95.7	93.7
-12	0.9	35.9	8.1	11.7	28.4	20.3	88.3	36.9	6.5	9.3	29.3	90.7	70.7
-13	5.7	33.9	9.1	5.4	14.1	45.9	94.6	35.0	7.0	2.3	27.4	97.7	72.6
-14	5.6	31.2	9.3	10.0	17.5	37.5	90.0	32.7	6.1	5.6	40.5	94.4	59.5
-15	5.5	34.0	9.7	6.9	16.6	43.6	93.1	35.3	7.2	3.4	31.2	96.6	68.8
-16	5.7	36.3	8.9	5.8	17.4	44.6	94.2	37.4	6.7	2.8	29.2	97.2	70.8
-17	5.8	32.2	9.2	4.1	17.1	46.8	95.9	32.8	7.6	2.2	20.9	97.8	79.1
-18	5.7	30.3	9.6	8.7	18.5	39.2	91.3	31.5	6.8	5.3	35.5	94.7	64.5
-19	6.0	30.6	9.9	3.7	16.9	42.0	96.3	31.1	8.6	2.0	15.6	98.0	84.4
-20	6.1	32.6	10.4	9.2	16.9	42.0	90.8	34.2	7.3	4.7	36.9	95.3	63.1
-21	5.7	22.1	9.1	5.9	34.2	31.8	94.1	21.3	7.6	9.1	20.5	90.9	79.5

Fig. 20.1 102 rpm

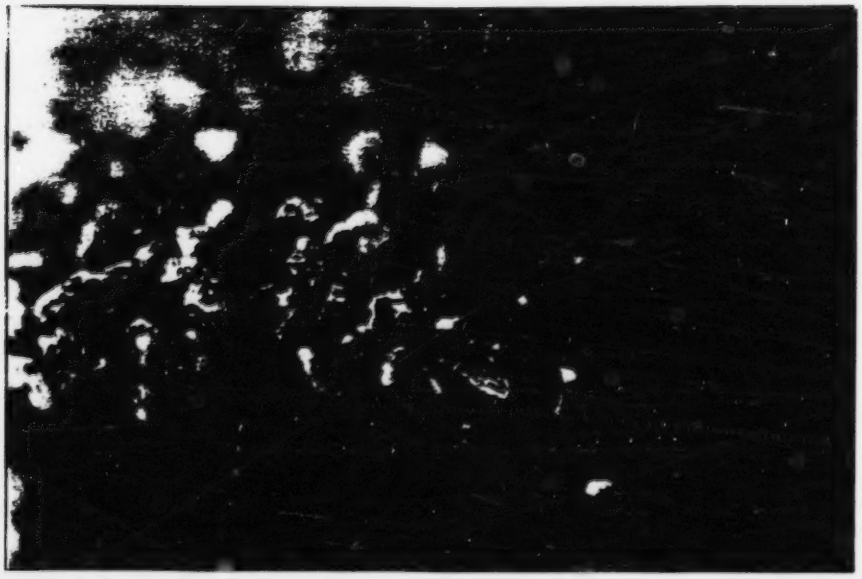

Fig. 20.2 27 rpm

Figure 20. Particle layers at various roll speeds (3 x 6 mesh fraction, 0.9 tph).

Fig. 20 .3. 9 rpm

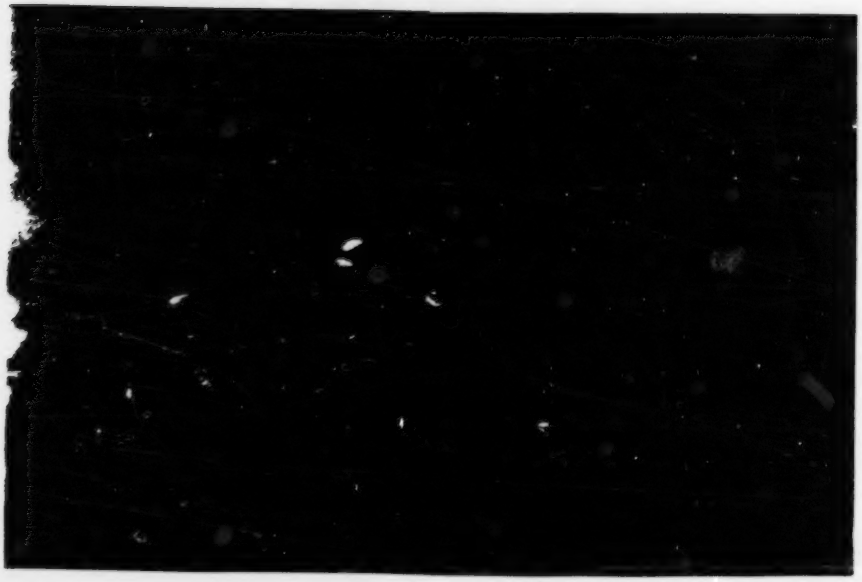

Fig. 20 .4. 5 rpm

Figure 20. Particle layers at various roll speeds (3 x 6 mesh fraction, 0.9 tph).

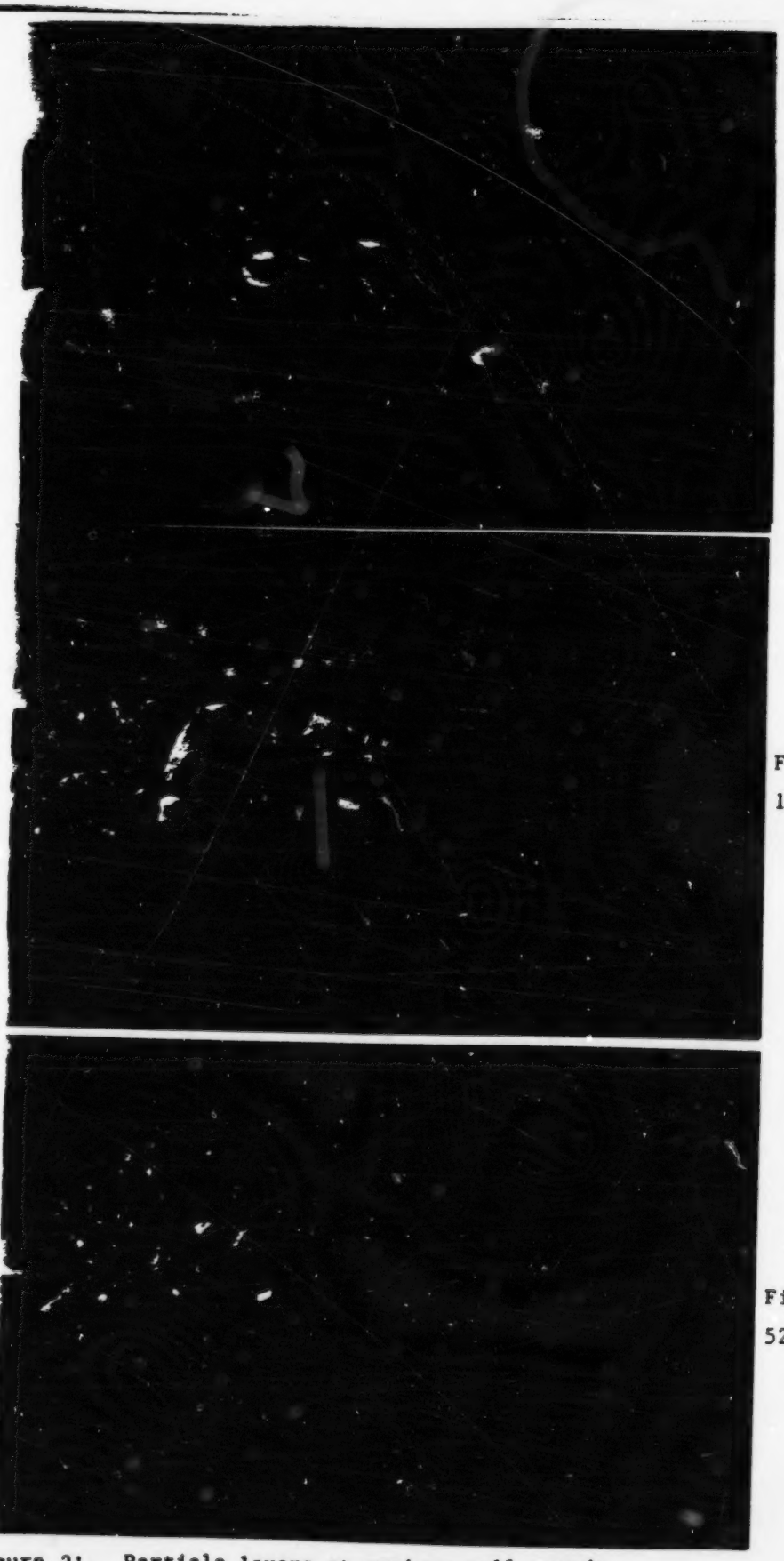

Fig. 21.1
150 rpm

Fig. 21.2
100 rpm

Fig. 21.3
52 rpm

Figure 21. Particle layers at various roll speeds (3 x 6 mesh fraction, 5.8 tph).

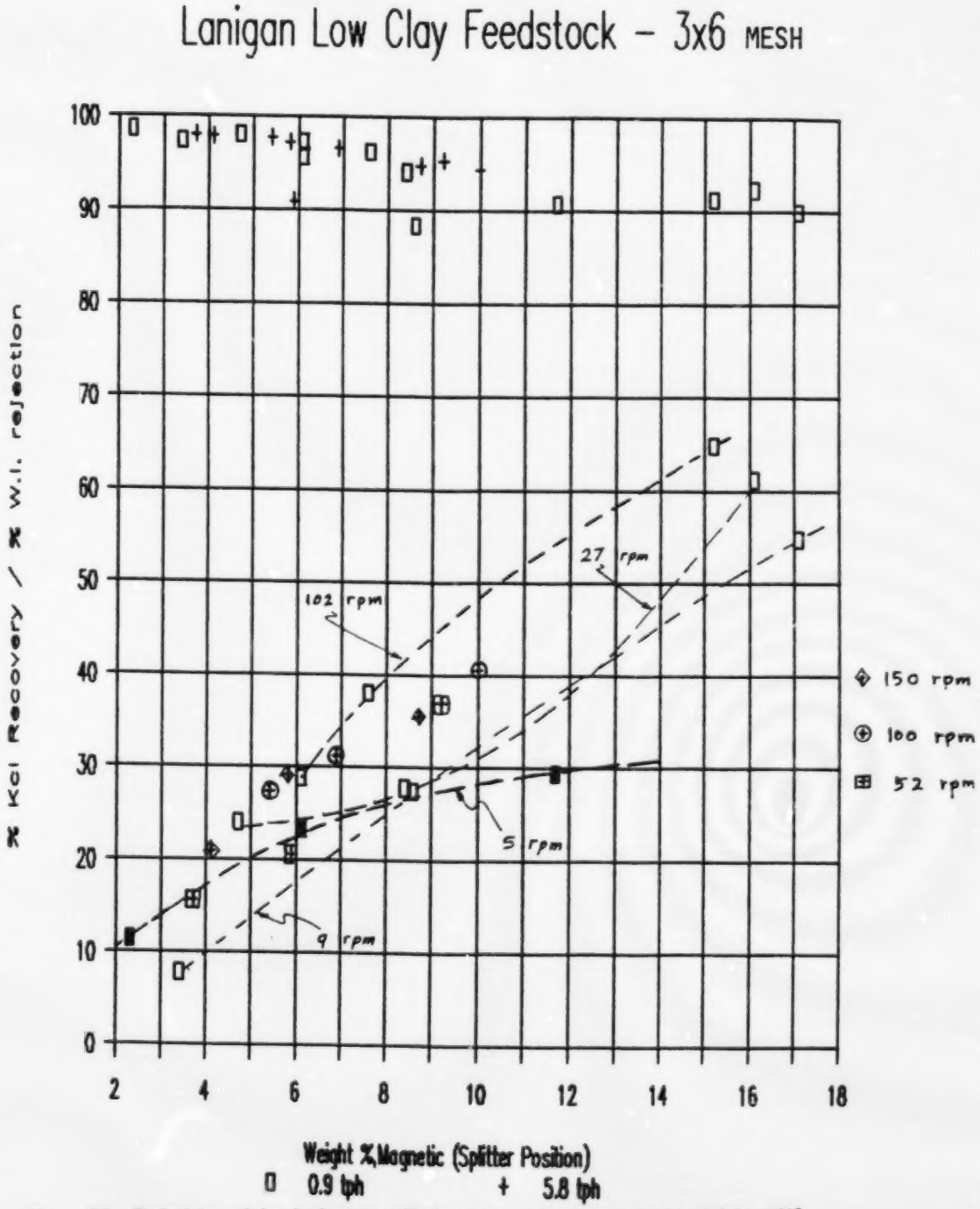

Fig. 22 Relationship between %Kcl recovery in non-magnetic, %WI rejection in magnetic and weight % magnetic(splitter gate position) - particle layers effect on separation

4.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

(1) Correlation for clay rejection and KCl recovery versus weight % magnetic streams has been established. The one meter, 100 mm diameter, single stage Permroll dry magnetic separator performed best on 3 x 6 mesh fractions at up to 8.7 tph feed rate, with 91% KCl recovery in the non-magnetics and 46% clay rejection in the magnetic. The finer 6 x 28 mesh fractions, because of wider particle size distribution, performed well at low feed rate (4-5 tph) but at high tonnage the clay rejection reduced significantly. For the 7/16" x 3 mesh fraction, about 35% clay rejection could be obtained at a fairly high (about 17%) weight split to the magnetic stream. The poor clay rejection is perhaps due to incomplete clay liberation. The 1" x 3 mesh fraction results in very poor separation because the particle sizes are too large and there is poor liberation of the 1" x 7/16" fraction.

(2) Throughput was limited by the particle layers (thickness) on the belt and was determined by the depth of magnetic field strength. As the particle becomes coarser, such as 3 x 6 mesh fraction, the monolayer or partially overlapped monolayer was the limited configuration for appropriate separation. A compromise had to be made amongst throughput and performance and particle size fraction.

(3) Double-pass seems necessary to improve clay rejection and reduce loss splitting to magnetic streams as occurring in a single-pass operation.

(4) The throughput and performance can be improved either with new magnetic material and matrix design for higher field strength, or with longer roll and double-pass configurations. Ore Sorters Inc. has recently proposed (2) to solve the throughput of the tested unit with a longer, 1.5 meter, roll to increase the unit capacity to 50%. Two 1.5 meter machines, which are to be positioned back-to-back drawing feed from one hopper, will triple the capacity of the tested unit. A single 1.5 meter separator with feeder would cost about $50,000 U.S., a double module $95,000 U.S. Ore Sorters also quote a double-pass 1.5 meter system with projected 50 tph capacity for $190,000 U.S.

Recommendations:

The potash separator worked reasonably well and was nearly trouble-free during this test work. However obvious drawbacks, such as the splitter gate, split hopper and vibrator pan, need to be modified. The splitter blade was extended at the pilot plant so that it could meet the deflected stream. The position of the blade in the current design was however not parallel to the stream trajectory consequently the differentiation between the magnetic and the non-magnetic streams turned out to be haphazand and difficult. The split hopper should be sloped so that material could flow easily, instead of catching around the edges and the corners. The guard (sides and back) should be extended higher so that higher tonnage can be tested without spilling over.

A double-pass separator is more ideal for pilot plant test work than the single-pass unit. With a double-pass separator, the feed handling step for the second-pass is totally eliminated and the problem of particle attrition, contamination and loss in fines, can be totally prevented. Data collection efficiency and accuracy can be greatly improved.

The data obtained from this report may not be conclusive. However, it reveals the practical aspect and the limitation of dry magnetic separation technology for potash clay removal. The data can be practically used for cost estimation, together with others such as screening, magnetic, and non-magnetic streams handling, etc. to evaluate the feasibility of such an application underground or on the surface.

5.0 REFERENCES

1. Hrynewich, W.S. "Dry Magnetic Separation of Insol from Sylvite and Halite"; CCP, 1987.

2. Private communication, 1987.